RESOURCE AND POTENTIAL RECLAMATION EVALUATION

BISTI WEST STUDY SITE
BISTI COAL FIELD

EMRIA

REPORT 5 -1976

U.S. Department of the Interior

Bureau of Land Management - Bureau of Reclamation - Geological Survey

EMRIA - Energy Mineral Rehabilitation Inventory and Analysis

EMRIA is a coordinated approach to collection, analysis, and interpretation of overburden, water, and energy-resource data. The main objective of the effort is to assure adequate base-line data for choosing reclamation goals and establishing lease stipulations.

These reports are prepared through the efforts of the Department of the Interior - principally by the Bureau of Land Management, Bureau of Reclamation, and Geological Survey. Assistance is also provided by other Federal and State Agencies.

Reports under this effort are listed in appendix A.

ACKNOWLEDGMENTS

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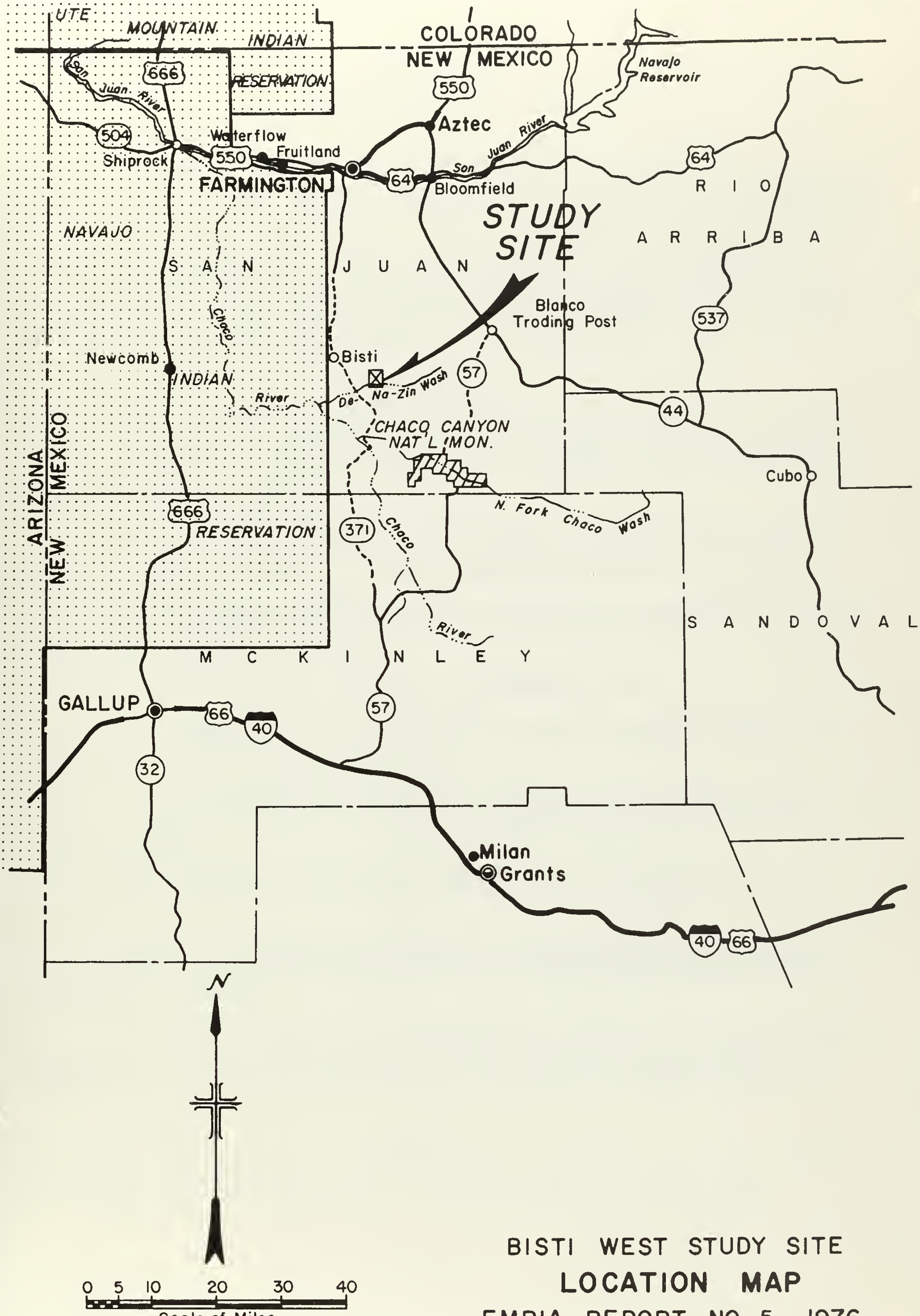

BISTI WEST STUDY SITE

LOCATION MAP

EMRIA REPORT NO. 5 -1976

FIGURE 1

CHAPTER I

INTRODUCTION

A growing and affluent society is creating an ever increasing need for energy. Attention has focused on the energy fuel sources of the Western States, primarily the Rocky Mountains and the Northern Great Plains Coal Provinces, due to the abundance, ease of extraction, and quality of the resources in these areas. It is the responsibility of the Bureau of Land Management (BLM) to assist in meeting these energy demands and, at the same time, provide sound reclamation and rehabilitation guidelines so that disturbed lands are returned to a useful state.

Objective

The principal objective of EMRIA studies is to assure adequate baseline data for choosing reclamation goals and establishing lease stipulations.

Other objectives include:

A. Provide data to minimize environmental impacts from surface mining of energy minerals on public lands administered by the BLM.

B. Provide environmental resource information needed to implement effective reclamation programs.

C. Provide resource and impact information for:

1. Preparation of Environmental Analysis Reports (EAR) and Environmental Impact Statements (EIS).

2. Use during site selection within the Secretary's energy leasing programs.

3. Support of State and local regional development and land use planning efforts.

D. Provide physical and chemical data from which realistic stipulations can be prepared for energy mineral exploration, mining, and reclamation planning.

E. Determine post-mining capabilities of surface soils and bedrock overburden overlying coal deposits to sustain a desirable vegetative cover.

Authority

Public Land Administration Act of July 14, 1960 (74 Stat. 506).

Responsibilities

Bureau of Land Management

A. Selects reclamation study sites for coordinated investigation of vegetation, soil, geological structure, surface water, and ground water.

B. Acts as contracting officer in the coordination, establishment, and execution of work orders (contracts).

C. Reviews and consolidates work order and field office data and prepares information for reports published by the Bureau of Reclamation.

D. Distributes technical data, reports, and reclamation and rehabilitation recommendations to BLM field offices.

Bureau of Reclamation (BR)

A. Evaluates land and overburden */ material as a source of suitable planting media in a revegetation program.

B. Conducts soil inventories

C. Recommends to BLM district office suitable plant species for areas to be revegetated.

D. Obtains core samples of bedrock and coal.

E. Installs casing in holes selected for ground water observation wells.

F. Prepares a geologic map.

G. Characterizes substrata immediately below the coal resources.

H. Advises BLM district office on reclamation techniques.

I. Publishes resource and potential reclamation evaluation.

Geological survey (GS)

A. Conducts studies of vegetative types and of moisture relationships in associated soils. Studies will result in vegetation maps and related soil characteristics.

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*/ Overburden is the consolidated material (bedrock) and unconsolidated material (surficial materials, such as soil, usually overlying the bedrock) overlying the coal.

B. Assesses reclamation potential based on water available from precipitation, effects of surface mining on area hydrology, and measures required to prevent adverse effects on area hydrology.

C. Prepares sediment yield maps.

D. Estimates annual runoff and peak flows.

E. Collects and interprets data to predict alternative solutions to ground water problems encountered during mining and reclamation.

F. Implements monitoring system to define baseline conditions and to document ground water flow and quality changes caused by mining and reclamation.

G. Prepares potentiometric maps.

H. Prepares geophysical well logs.

I. Estimates coal resources.

J. Performs laboratory tests on coal resources.

K. Graphically presents results of laboratory tests on coal resources.

1. Vertical direction - Plotted against well logs.

2. Horizontal direction - Using plan view, if significant.

Setting

The study site */ is located about 35 miles south of Farmington, New Mexico (see figure 1, preceding page 1). It includes some of the "Bisti Badlands," long recognized as unusual geologic formations with scenic colors. Most of the study site lies outside the badlands in flats spotted with sparse vegetation.

The paleontology of the Bisti Badlands has been intensely studied by others. Numerous collections have been made. some of which are exhibited by the Denver Museum of Natural History in Denver, Colorado, and the Smithsonian Institute in Washington, D.C.

Coal outcrops are evident on the study site. Local Indians have mined coal outcrops for many years as fuel for cooking and heating. Coal deposits in the area west of the study site have been under lease since

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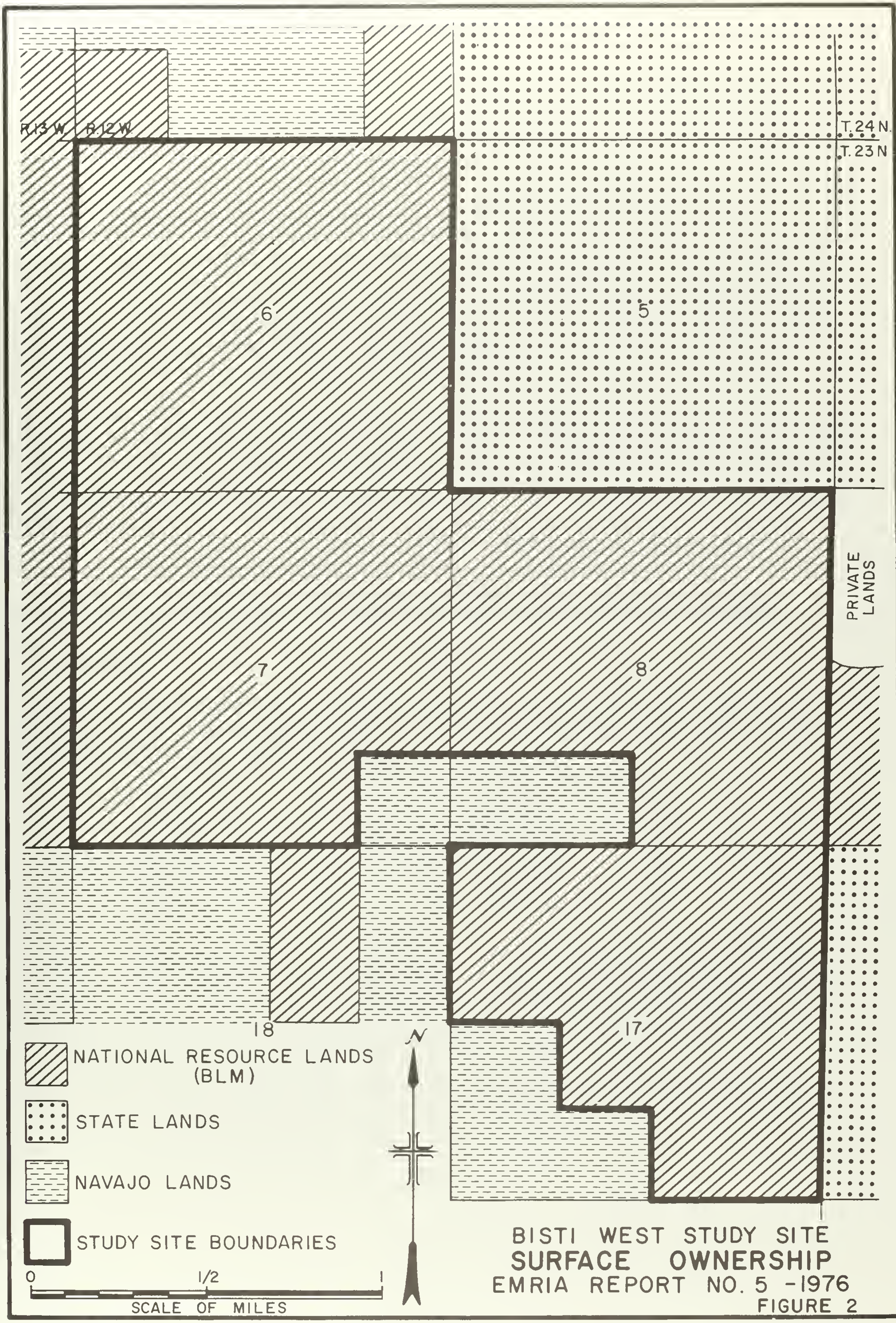
*/ The study was conducted during the period from July 1975 to January 1977. The study site consists of 2,320 acres.

Looking south from Alamo Mesa, near DH-1. Edge of mesa in foreground; badlands in middle ground; valley lands and De-Na-Zin Wash (light streak) in background. Picture illustrates typical features of study site. (See Figure 4 for location of DHs and AHs used in photo references) (4-76)

Alamo Mesa coarse-textured Class 3 land and its typical vegetation. Picture taken near DH-1 looking southwest. (4-76)

August 1961. Areas to the north and east are under preference right lease application.

Wildcat exploration for oil and gas has been conducted in the past. Currently, the land in the Bisti West area is used for livestock grazing. Indians in the area depend on goats and sheep for income and have horses for herding purposes. Other ranchers in the area raise cattle. Surface ownership at the study site is shown on figure 2.



BISTI WEST STUDY SITE
SURFACE OWNERSHIP
EMRIA REPORT NO. 5 -1976
FIGURE 2

CHAPTER II

PHYSICAL PROFILE

Climate

Distant high mountains shield this area from shallow intrusions of extremely cold air in winter. Mountains also block the area from much Pacific air precipitation; and before it reaches northwestern New Mexico, air from the Gulf of Mexico loses most of its moisture. This lack of precipitation is an important aspect of the harsh climatic picture which emerges from the data that follows. The Bisti West site is an arid area where harmful extremes of all climatic factors important in vegetative growth are more the rule than the exception.

There are several long-term meterological stations within a 35-mile radius of the Bisti West study site. These include Bloomfield, Farmington, and Fruitland to the north; Newcomb to the west; and Chaco Canyon National Monument to the south. These stations range in elevation from 5165 feet at Fruitland to 6125 feet at Chaco Canyon. The study site, at an approximate elevation of 5900 feet, does not have a permanent meteorological station. (A network of 12 nonrecording rain gages has been installed as part of an EMRIA hydrological monitoring program for the site, but data are not yet available.) All climatological data for the site were therefore estimated based on data from the above long-term stations.

Temperature

Based on data from these stations, the Bisti West study site has an average annual temperature of 52°F. Monthly average temperatures (°F) for the study site were estimated as follows:

January	29	July	76
February	35	August	73
March	41	September	66
April	51	October	54
May	59	November	40
June	70	December	30

Extreme temperatures in San Juan County are 110°F and -35°F. Temperatures rarely reach 100°F, however, and on only a few days a year fall to zero or below. The average daily range of temperatures is about 33°F. Frequent freezing and thawing of the surface takes place in December through March, when nighttime temperatures average below freezing.

Freeze data for the Bisti West study site were based on the 1966-1975 records for Bloomfield and Chaco Canyon, which are summarized in table 1.

Table 1
Study Site Freeze Data

	Date Last Spring Minimum of			Date First Fall Minimum of			No. of Days Between Dates		
	24°	27°	32°	32°	28°	24°	24°	28°	32°
Bloomfield (Elevation 5794)									
Earliest	3/21	3/27	4/15	10/5	10/8	10/18			
Latest	5/2	5/7	5/19	10/30	11/15	11/27			
Average	4/12	4/24	5/1	10/19	10/27	11/6	212	187	171
Chaco Canyon (Elevation 6125)									
Earliest	4/21	4/30	5/16	8/21	8/24	8/29			
Latest	5/23	6/26	6/26	10/9	10/15	10/16			
Average	5/11	5/29	6/5	9/19	9/26	10/2	145	120	106
Bisti West (estimate based on elevation 5900)									
Earliest	3/30	4/6	4/24	9/20	9/23	10/2			
Latest	5/8	5/22	5/30	10/23	11/5	11/13			
Average	4/21	5/5	5/12	10/9	10/17	10/25	188	166	151

As can be seen, there is considerable difference in the Bloomfield and Chaco Canyon values. The Bisti West study site values are estimated on the basis of relative elevations at the three locations. This estimate is not precise, of course, but should be a reasonable figure. As with all climatic data, these averages can be deceiving--note that all minimums show over a month's difference between their earliest and latest dates.

Precipitation

Average annual precipitation at Chaco Canyon is about 8.5 inches; at Bloomfield and Farmington about 8 inches; and at Fruitland about 7.5 inches. Newcomb averages only about 5.5 inches because it is in the rain shadow of the Chuska Mountains. There is a hint of the usual topographic influence, excluding Newcomb, in that Chaco Canyon is the highest in elevation and precipitation, and Fruitland the lowest. Most of the data for the area indicate that the Bisti West study site should average about 8 inches a year. Monthly precipitation for the study site in inches was accordingly estimated as follows:

January	0.5	July	0.9
February	0.5	August	1.2
March	0.6	September	1.0
April	0.5	October	0.9
May	0.5	November	0.4
June	0.4	December	0.6

As can be seen, half of the annual precipitation occurs in late summer and early fall, when thunderstorms are most active. These are localized, often intense storms, which can cause flash flooding and heavy erosion. Rainfall intensity and frequency are estimated in table 2.

Extreme variations in these average values could occur. Near the study site, annual precipitation ranges from about 4 to 20 inches; during many individual months precipitation is zero; occasionally for two successive months precipitation is zero; and even for three successive months precipitation has been recorded as zero.

The amount of total precipitation which is effective can be directly related to intensity of precipitation. Generally, effective precipitation is determined on a monthly basis with the first inch considered 95 to 100 percent effective. Determining effective precipitation this way, on an average basis, the annual precipitation of 8 inches at the Bisti West study site appears to be close to 8 inches of effective precipitation. The intensity-frequency data tabulated above indicate, however, that 7 inches would be a better approximation of an average value. Under certain soil and slope conditions--such as soils with low infiltration rates and steep slopes--this figure will be much less. These conditions are prevalent at the study site.

Table 2

Estimated Rainfall Frequency For Bisti West Study Site

(Unit: Inches)

Duration Hours	Frequency (Years) 1	2	5	10	25	50
.5	.4	.5	.8	1.0	1.2	1.4
1	.5	.6	.9	1.2	1.4	1.7
3	.7	.9	1.3	1.7	1.9	2.2
6	.8	1.2	1.5	1.9	2.2	2.4
12	.9	1.4	1.9	2.3	2.6	2.8
24	1.1	1.5	2.0	2.4	2.9	3.0

The snowfall season is November through April, with an annual average total of about 9 inches. Hail occurs occasionally in association with the late summer and early fall thunderstorms.

Other climatic characteristics

While winds at higher altitudes move generally from west to east, surface winds are greatly modified by local topography. During much of the year, high-pressure systems and fair weather are dominant; calms are frequent but usually short in duration. Surface winds move up the valley slopes during the day and down the slopes at night. Spring is the windiest season, with winds averaging 10 miles per hour. Wind speed is highest, however, during the summer months. Strong winds up to 25 miles per hour are most common from the west. Very strong winds, occasionally up to 70 miles per hour, are associated with local thunderstorms and thus are of short duration. In the San Juan Basin, particularly in the Chaco River drainage area, the dry exposed topsoil, scanty vegetation, and turbulent winds cause much blowing dust during the dry months from November to April. Dust devils, vertical vortexes of rapidly moving dust-laden air, are common in the summer.

Average relative humidity is nearly 50 percent, ranging from 70 percent in the early morning to 30 percent in the afternoon. In late spring and early summer, afternoon relative humidities are 15 to 20 percent.

Pan evaporation at Farmington is 53 inches annually. Inasmuch as evaporation is usually related to elevation, evaporation at the Bisti West study site would be somewhat lower, probably about 50 inches a year.

Effect of weather on site revegetation

Several weather-related factors will definitely have adverse effects on revegetation of the Bisti West study site. Low annual precipitation rates compounded with erratic distribution patterns and high summer storm intensities create unfavorable conditions for seed germination and plant growth. The effectiveness of the incoming precipitation is further reduced by the occurrence of shallow soils over much of the area and by relatively low soil infiltration rates. Strong spring winds tend to remove soil moisture that could otherwise be utilized in seed germination, seedling establishment, and general plant growth. Dry, cold, windy winters may also result in relatively high percentages of winterkill among recently established vegetation.

Climate and aspect (exposure). South-facing slopes at the study site will characteristically be subjected to more droughty conditions than slopes with northern aspects or exposures. These droughty conditions result primarily from the prevailing dry west and southwest winds and from higher temperatures due to greater amounts of incoming solar radiation. Soil movement due to wind erosion may expose the tender roots of plant seedlings or bury the seedlings entirely.

Evapotranspiration demand. The Bisti West study site has an estimated annual pan evaporation rate of about 50 inches and an annual precipitation rate of only 8 inches. High temperatures, low precipitation rates, low humidities, and regular winds result in plant moisture deficits far exceeding available annual moisture levels. This is especially true during the summer growing season. Therefore, revegetation of the study site must be accomplished using native plant species characteristic of the immediate area, which have shown the adaptations or inherent abilities to withstand the high summer moisture deficits and overall climatic conditions.

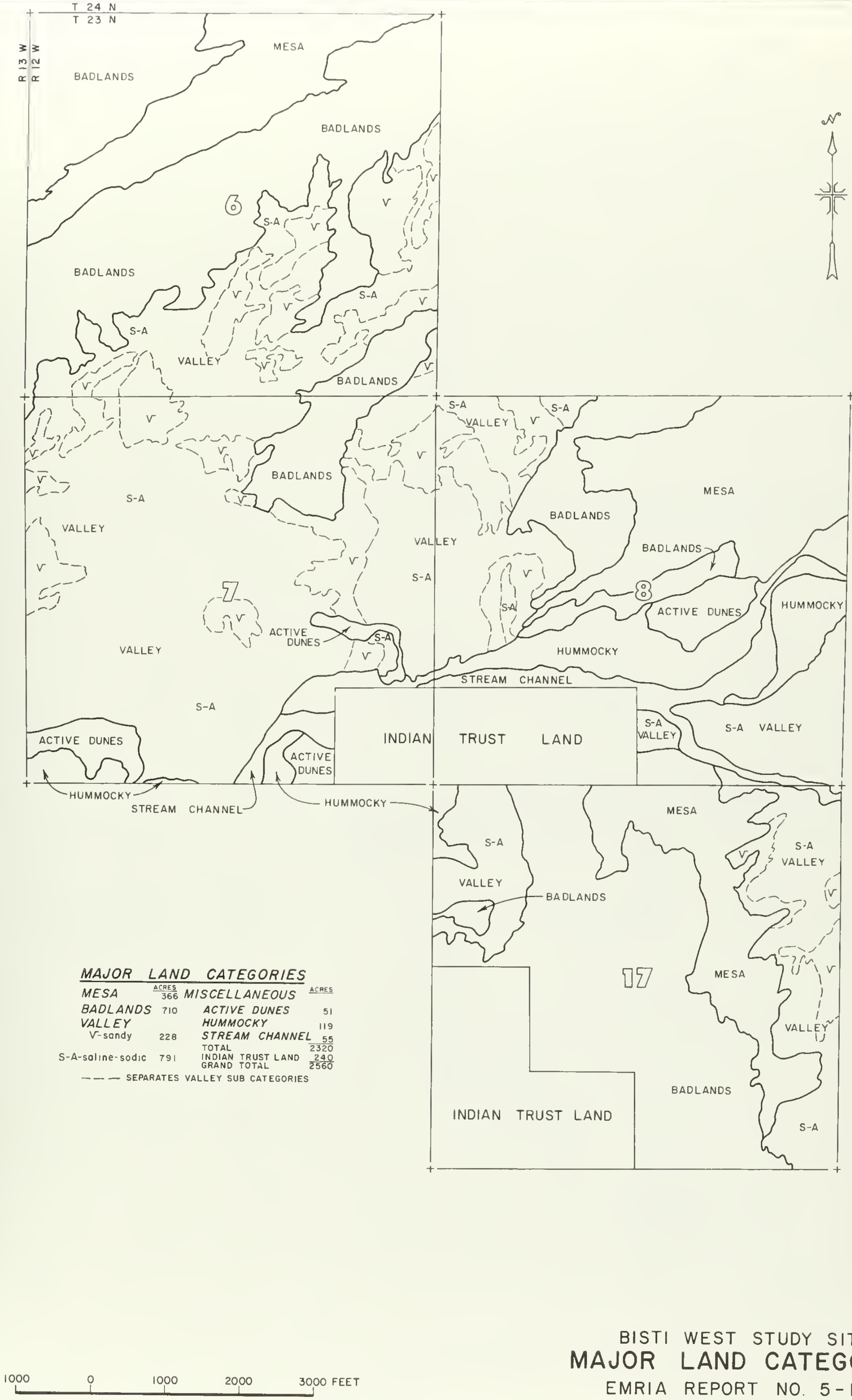
Physiography, Relief, and Drainage

The study site is situated in the Navajo Physiographic Section of the Colorado Plateau Physiographic Province, which in turn is in the Intermontane Plateaus, a major physiographic division of the United States.

The Navajo physiographic section comprises a large region of northwestern New Mexico and northeastern Arizona. The bold contrasts of the section's landforms are characterized by young plateaus, mesas, hogbacks, retreating escarpments, and debris-choked dry wash canyons. Though there are numerous cliffs and escarpments, talus accumulations are rare. Precipitation is low to moderate, the latter at the higher elevations. The section's San Juan River is the only stream which collects runoff from outside the section. Vegetation consists mostly of sagebrush, bunchgrasses, and their associates. In places vegetation gives way to bare soil, bare rock badlands, or active sand dunes.

The physiographic subdivision of the Navajo Section which contains the study site is the Chaco Plateau. Boldly scarped, rolling, broad plains and mesas characterize the Chaco Plateau. Youthful canyons of badland topography indent the abrupt escarpments bordering the uplands. Wide swales trenched by sand-choked dry wash canyons are starkly cut into the plains. The effects of erosion by wind and water are graphically evident, and landforms are determined by the relative resistance and attitude of the rock formations.

The study site is an area of sharp contrasts, including badlands, boldly scarped mesas, sand dunes, and sand-choked dry washes (figures 3 and 4). The most conspicuous topographic feature is Alamo Mesa (in section 6), which forms the drainage divide between Alamo Wash to the northwest and De-Na-Zin Wash on the study site. Most areas of the mesa tableland have some vegetation. The mesa top has some active dunes and a few small hummocky areas, but it is mostly gently sloping lands. The mesa's steep sides and bordering areas are a stark but scenic intaglio of barren badlands. Badlands also occur locally in the SE 1/4, sec. 8, and locally in sec. 17. Elsewhere in the study area, terrain is fairly level to rolling and hummocky.

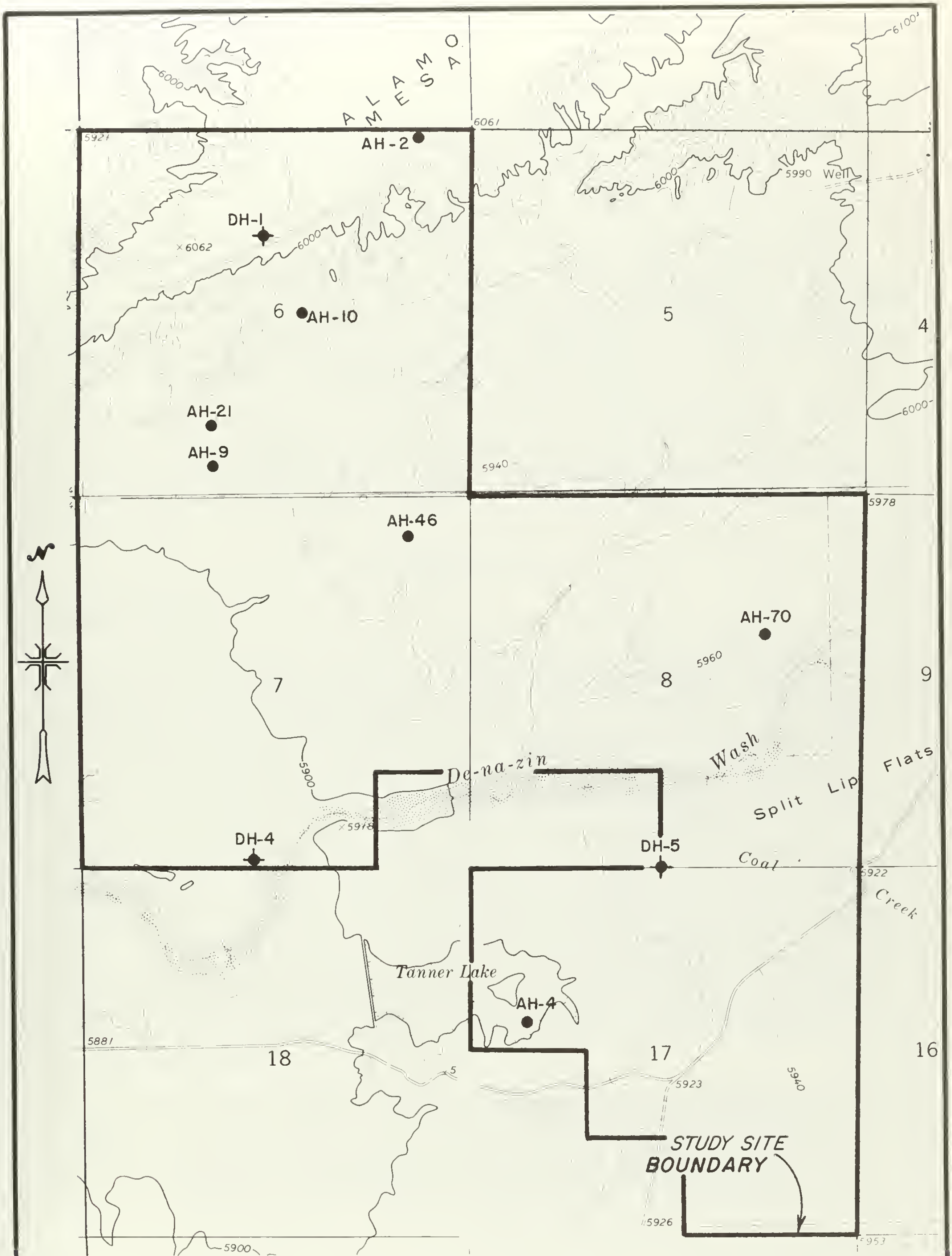


BISTI WEST STUDY SITE

MAJOR LAND CATEGORIES

EMRIA REPORT NO. 5-1976

FIGURE 3



AH-4 ● DH-5 ✦ Auger or drill hole used as photo reference.

1000 0 1000 2000 3000 4000

Scale in Feet

BISTI WEST STUDY SITE
TOPOGRAPHY
EMRIA REPORT NO. 5-1976
FIGURE 4

Major drainage in the area of the study site is to the west and southwest to Chaco River, a left tributary to San Juan River. De-Na-Zin Wash is the largest drainage in the study site, crossing it just below center in west-southwest direction, with a gradient of about 30 feet per mile. Coal Creek, from the southeast, is the major tributary to De-Na-Zin Wash (confluence in sec. 8). Several dry washes tributary to De-Na-Zin Wash trend south-southwest from the Alamo Mesa scarp and bordering badlands at gradients ranging from 100 to about 30 feet per mile. Thin to non-existent soil cover and vegetation, the poorly pervious nature of some soils and of the underlying rock formations, and relatively steep gradients are primary factors which could result in high runoff. Infrequent but sometimes intense rainstorms change the otherwise dry sand-choked channel of De-Na-Zin Wash to a raging sediment-laden torrent.

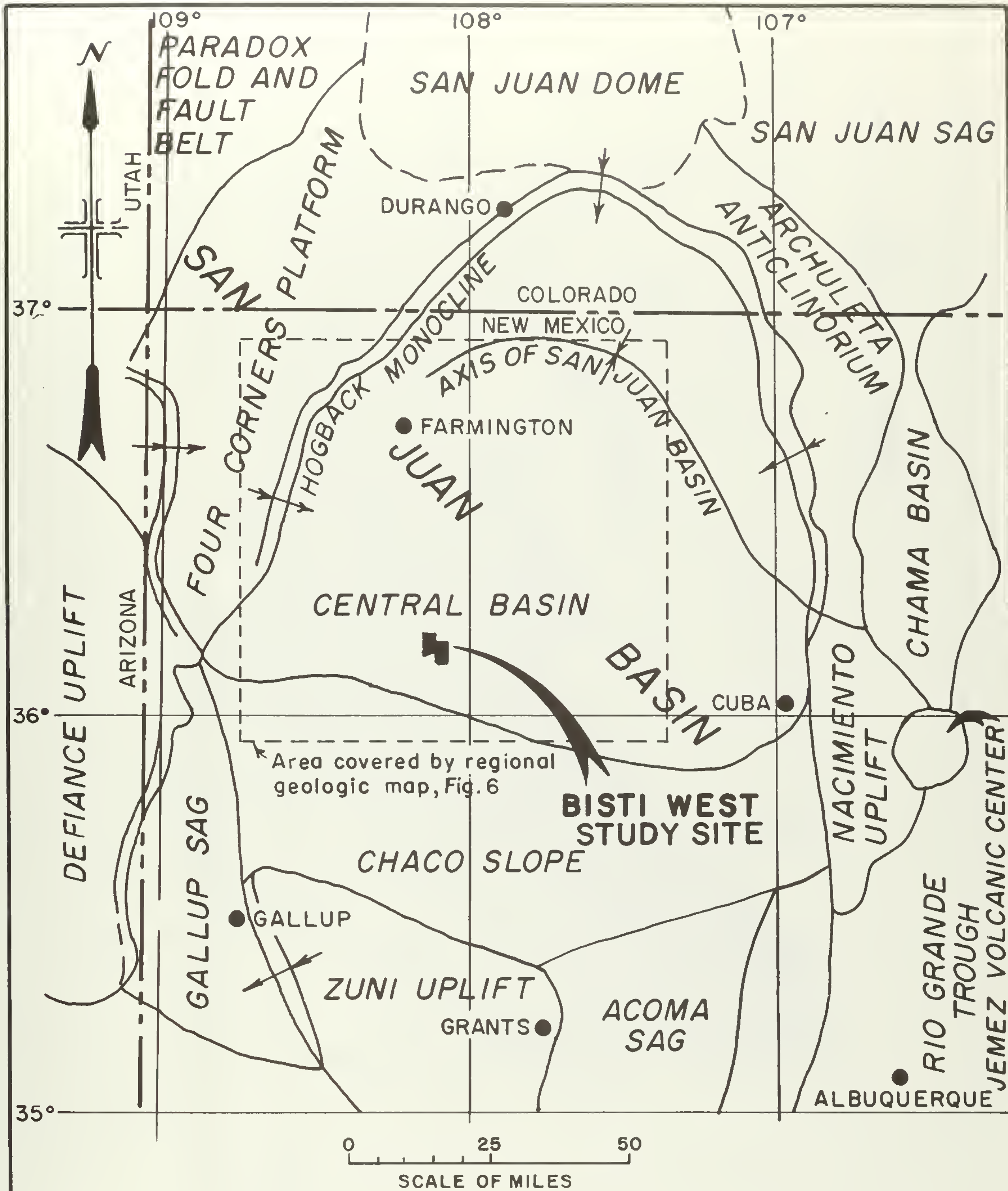
Elevations range from 5870 to 5960 feet over about 85 percent of the study site. Exceptions are found in the N 1/2, sec. 6, on Alamo Mesa and along its scarp and flanks where elevations range from 5960 up to 6062 and in the NE 1/4, sec. 8, where elevations range from 5960 up to about 5980.

Geology

Regional geology

The major structural element of the region which includes the study site is the San Juan Basin--a circular, intermontane, structural element encompassing a large region in northwestern New Mexico and southwestern Colorado. Structural elements of the basin are shown on figure 5. The basin is one of several interspersed or embayed into the ranges of the Rocky Mountains between New Mexico and Canada. The boundaries of the basin are in places sharply defined by monoclinal folding and associated hogbacks, or by faulting, while in other places the basin merges into adjoining depressions or uplifts. The basin is asymmetric, its axis being located in the northeast quadrant of its Central Basin. The Central Basin has a broad south limb dipping gently northwest, on which the study site is situated, and a narrower, more steeply dipping north limb. Thus the study site is in the southwestern quadrant of the Central Basin of the San Juan Basin. The rocks within the Central Basin and study site are clastic sedimentaries of Late Cretaceous age. They are undisturbed by faulting, though a few broad folds with gentle dips are reported. Gas production within the Central Basin is largely from stratigraphic traps.

The San Juan Basin contains clastic and minor chemical sedimentary rocks ranging in age from Cambrian to Quaternary, having a maximum total thickness exceeding 14,000 feet in the deepest or axial northeastern part of the basin. The nomenclature, ages, and surface distribution of the rocks pertinent to the study site area are shown on figure 6.



NOTE:
Drawing adapted from U.S. Geological Survey Professional Paper 552, Figure 5

STRIP MINE REHABILITATION STUDY
BISTI WEST SITE - NEW MEXICO

STRUCTURAL ELEMENTS OF SAN JUAN BASIN

FIGURE 5

EXPLANATION

TERTIARY
Non-Marine

Tsj — SAN JOSE FORMATION:

Massive, thick-bedded sandstone and interbedded lenticular shale

Ttp — NACIMIENTO FORMATION:

Varicolored shale, siltstone, and mudstone with interbedded and lenticular sandstone and conglomeratic sandstone

CRETACEOUS
Marine and Non-Marine

Koa — OJO ALAMO SANDSTONE

Massive sandstone, conglomeratic sandstone, comglomerate, and minor shale

Kmd — MCDERMOTT MEMBER

Shale, sandstone, and volcanic debris

Kk & Kkf — KIRTLAND SHALE

Includes upper and lower shale members (Kk), and the Farmington sandstone middle member (Kkf)

Kf — FRUITLAND FORMATION:

Massive carbonaceous shale, sandstone, siltstone, and coal.

Kpc — PICTURED CLIFFS SANDSTONE

Predominantly sandstone with minor shale and siltstone

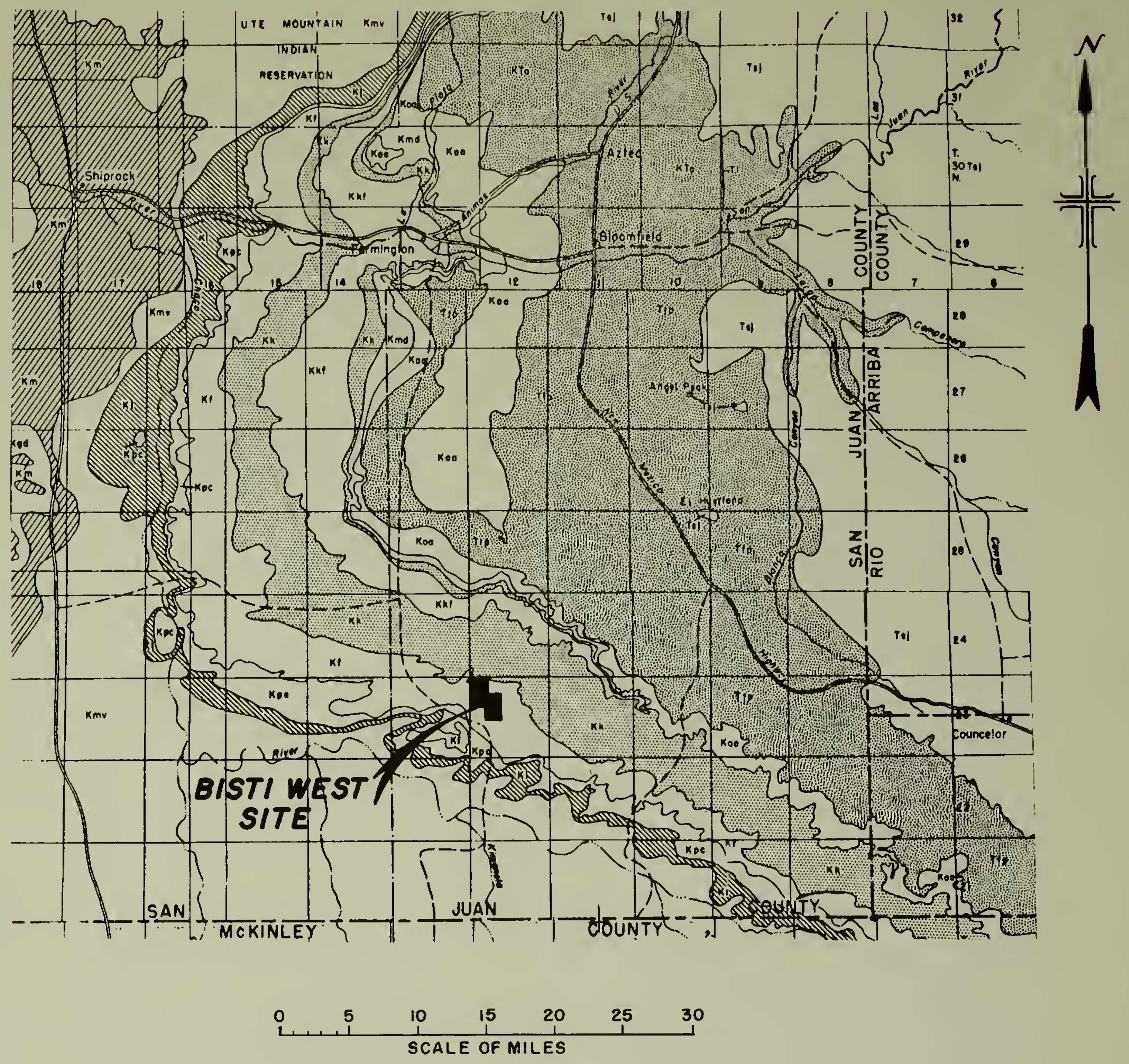
Kl — LEWIS SHALE

Predominantly shale with minor thin siltstone and sandstone

Kmv — MESAVERDE GROUP, UNDIFFERENTIATED:

Shale, sandstone, siltstone, and coal. Includes Mancos shale (Km) and Dilco coal and Gallup sandstone members (Kgd)

NOTE: Reproduced in part and adapted from: New Mexico Geological Society Guidebook of the San Juan Basin, First Field Conference, 1950, Geologic Map of the San Juan Basin, by Caswell Silver.



STRIP MINE
REHABILITATION STUDY
BISTI WEST SITE - NEW MEXICO

REGIONAL GEOLOGY

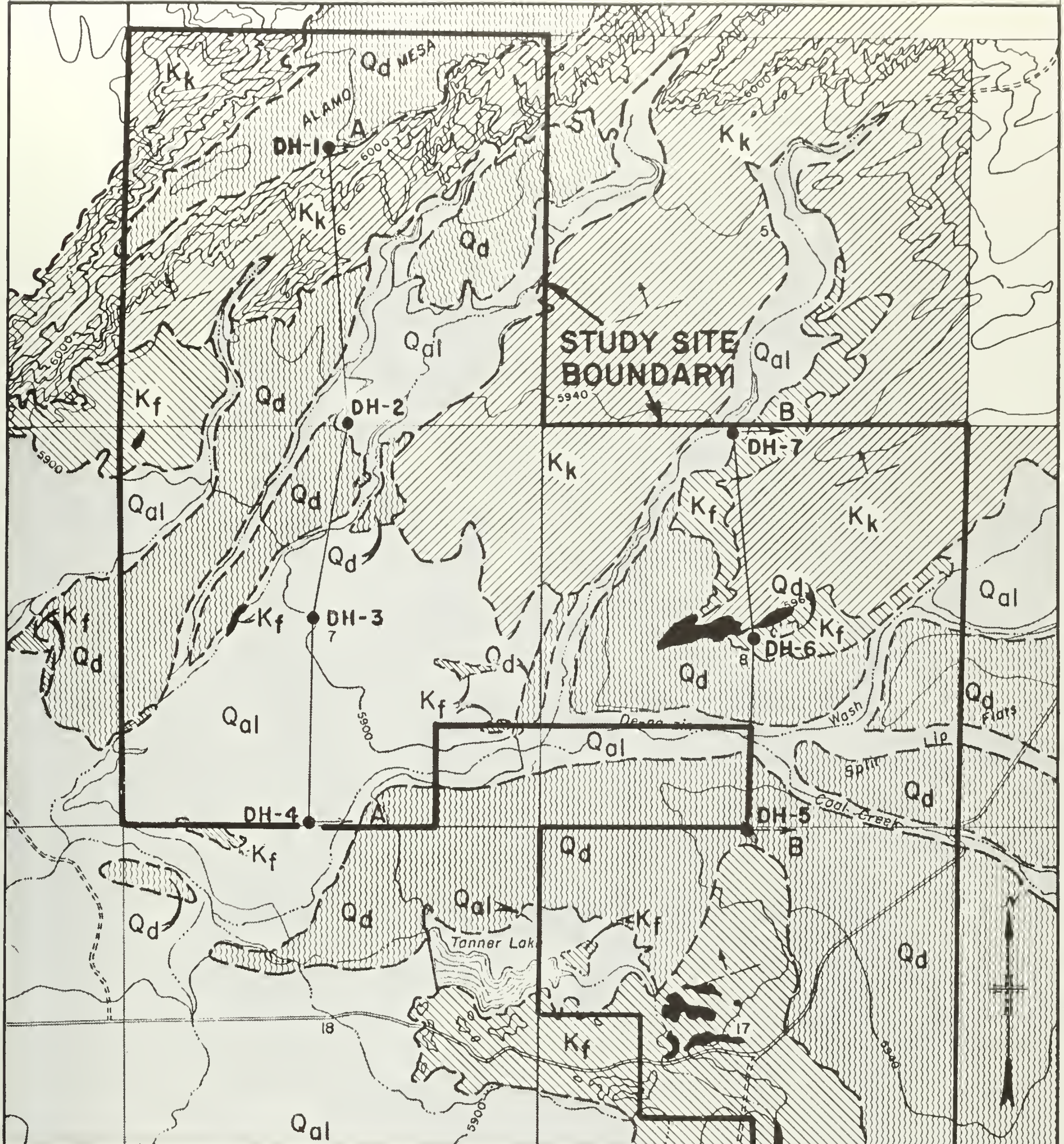
FIGURE 6

The varied rock sequence of the San Juan Basin reveals many epochs of marine and nonmarine deposition. A complex sequence of Paleozoic sandstone, conglomerate, limestone, shale, gypsum, and a number of unconformities attest to alternating cycles of submergence and emergence. During the Mesozoic Era the San Juan Basin was primarily an emergent area at which time fluviatile sediments of sandstone and shale were deposited. During the early part of the Late Cretaceous Epoch, however, seas advanced across the area, depositing the transgressive sandstone of the Dakota Sandstone and marine shales of the Mancos and Lewis Shales. The onset of the Laramide orogeny in the late Cretaceous period resulted in a retreat of the sea and deposition of the regressive sandstone of the Pictured Cliffs Sandstone. The superjacent Fruitland Formation contains carbonaceous shale, sandstone, siltstone, and coal which were laid down in swamp and flood plain environments on coastal lowlands adjacent to the eastward-retreating Cretaceous sea. The Kirtland Shale, which overlies the Fruitland Formation, consists of upper and lower shale members and a middle sandstone member which represent swamp, flood plain, and channel deposits. As the Cretaceous period closed, increasing orogenic activity and vulcanism flooded the San Juan Basin area with detritus, which constitutes the McDermott Member and other parts of the Animas Formation and parts of the Ojo Alamo Sandstone. Orogenic and volcanic activity continued well into Paleocene time in the Cenozoic Era, as evidenced by andesitic detritus of the Animas Formation and fluviatile sands and silts of the Nacimiento Formation. A late episode of this orogenic activity is evidenced by the Eocene San Jose Formation, a "basin-filling" sequence of sandstone and shale derived from rising fold belts to the east, north, and west. During this episode, the prominent structural features of the basin rim were formed, including the Gallup Basin, Defiance Uplift, Hogback Monocline, Archuleta Anticlinorium, and Nacimiento Uplift. In late Cenozoic time the San Juan Dome was formed by volcanic activity and emplacement of intrusive igneous bodies contemporaneous with elevation of the San Juan Basin area. In relatively recent geologic time erosion by water, wind, and glaciation has developed the present landscape, characterized by buttes, mesas, and dry-wash canyons in the basin, and by hogbacks, ridges, and mountains on the rims.

Study site geology

Investigations. Seven Nx-size (3-inch diameter) core holes, designated DH-1 through DH-7, were drilled at the Bisti West site. Locations of the holes are shown on figure 7.

Three of the holes (DH-3, DH-5, and DH-7) were deepened approximately 200 feet each by drilling without coring for ground water studies by the GS. Two-inch-diameter perforated plastic pipe was installed in these holes. Geologic logs were not prepared for the deepened parts of the holes; however, geophysical logging of the holes was done by GS.



EXPLANATION

QUATERNARY

Qal — Alluvium. Includes fine silty sand in De-Na-Zin Wash, Coal Creek, and tributary drainages, clayey-silty-sandy residual soils, and sandy slopewash accumulations. Also includes local areas of sandy aeolian deposits.

Qd — Dune Sand. Predominantly silty fine sand in inactive and locally active sand dunes.

CRETACEOUS

Kk — Kirtland Formation. Predominantly shale with lesser amounts of interbedded sandstone and siltstone.

Kf — Fruitland Formation. Predominantly shale, organic shale, and coal with interbeds of sandstone and siltstone.

Approximate Geologic Contact

Approximate directions of dip and strike of beds. Dip angles of beds are less than 2°, as determined by calculations using the 3 point method.

Approximate location of coal outcrop

1 0 1 2 3 4 5

SCALE OF MILES

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

STRIP MINE
REHABILITATION STUDY
BISTI WEST SITE
GEOLOGIC MAP

DESIGNED .... SUBMITTED ....
DRAWN .... RECOMMENDED ....
CHECKED .... APPROVED ....

AMARILLO, TEXAS | APRIL 1976 | FIGURE 7

Continuous Nx-size coring was done from top of formation rock to depths sufficient for penetration of all beds of coal in the Fruitland Formation and into the underlying Pictured Cliffs Formation. Bentonite drilling mud and water were used as the drilling medium, except between depths 0 and 81.6 feet in DH-1, where air was used. Overall core recovery was excellent to good. Core recovery was 100 percent in all beds of coal, except in DH-1 between depths 132.3 and 137.8 feet, where 63 percent was recovered; in DH-3 between depths 53.4 and 57.7 feet, where 57 percent was recovered; and in DH-4 between depths 40.3 and 50.3, where 80 percent was recovered. All coal core samples were sealed in plastic bags immediately after removal from the core barrel and were shipped to the GS, Denver, for testing and analysis. For each core hole, two samples (each 10 to 12 pounds) of each lithologic unit were thoroughly cleaned to remove the drill-mud coating, sacked, and shipped to the BR laboratory, Lower Missouri Region, Denver, Colorado, for physical and chemical analyses. The remainder of the core samples were stored at the BLM warehouse, Farmington, New Mexico. Samples of mud and water used in drilling were collected and furnished to the above GS and BR Denver offices.

A BR geologist mapped the study site during the winter of 1975-76. Aerial photo interpretation and field checking were used to delineate the various geologic units. The study site geologic map, figure 7, was compiled using GS 7.5-minute quadrangle topographic maps for base.

Geology. Surficial materials in the study site consist predominantly of sandy gently sloping areas on Alamo Mesa and hummocky areas concentrated along De-Na-Zin Wash and its major tributaries and locally on Alamo Mesa. An area of active sand dunes is situated on the south side of De-Na-Zin Wash downstream from Tanner Dam. Alluvial deposits of sand-silt mixtures choke the channel of De-Na-Zin Wash. Thin accumulations of sandy-silty-clayey slope wash derived from adjacent steep terrain occur locally within the area. The development of residual soils and vegetative growth has been retarded or precluded over relatively large areas due to unfavorable chemical constituents present in much of the underlying formation rock. Moisture infiltration rates and retention capabilities of the soils may also be factors in the retardation or preclusion of the development of vegetative growth. These barren areas appear as badlands carved by wind and water erosion.

The Late Cretaceous Age sedimentary rock formations outcropping over much of the study site area belong, in ascending order, to the Pictured Cliffs Sandstone, Fruitland Formation, and Kirtland Shale. The formations dip to the northwest, toward the axis of the San Juan Basin, at angles of less than 2 degrees; consequently, the Pictured Cliffs Sandstone which outcrops immediately south of the study site area is succeeded successively northward in the area, or downdip, by the outcrop belts of the younger Fruitland Formation and Kirtland Shale. Outcrops of the formations are delineated on figure 7. Depth intervals in which the

Looking south from Alamo Mesa, near DH-1, at badlands (Kirtland formation). Note active sand dune in foreground. (2-76)

View illustrating concretions weathering out of Kirtland formation on south side of Alamo Mesa. (2-76)

formations were cored or drilled in DH-1 through DH-7 are identified in interpretive notes on the geologic logs (appendix D).

The Pictured Cliffs Sandstone is underlain by the Lewis Shale of Late Cretaceous Age, which consists of beds of clayey, silty shale and minor thin sandstone, ranging from 200 to 500 feet in thickness. The Lewis Shale in turn rests on sedimentaries of shale, sandstone, coal, limestone, gypsum, salt, and quartzite more than 10,000 feet in total thickness that range in age from Cambrian to Late Cretaceous.

The Pictured Cliffs Sandstone in the study site consists predominantly of fine-to-medium-grained sandstone which is silty and slightly clayey, weakly cemented and friable, massively bedded, and light gray to gray. Minor thin beds of siltstone and shale are reported in the literature. The lithology and fossils of the formation indicate the rocks were deposited in littoral and offshore marine environments at a time when the shoreline of the Cretaceous sea was regressing northeast across the area. The Pictured Cliffs Sandstone is considered one of the most important gas-producing formations in the central and northern parts of the San Juan Basin.

The contact between the Pictured Cliffs Sandstone and the overlying Fruitland Formation is arbitrarily placed at the top of the uppermost massive sandstone in the Pictured Cliffs Sandstone below the lowermost coal in the Fruitland Formation. Coring at drill holes DH-1 through DH-4 penetrated 30.5 to 40.5 feet of the upper part of the Pictured Cliffs Formation, while lesser footage was cored at DH-5 through DH-7. Drilling without coring at DH-3, -5, and -7 did not extend below the base of the formation, indicating that the Pictured Cliffs is more than 200 feet thick.

Overburden materials in the Fruitland Formation and Kirtland Shale and materials separating the Fruitland coal beds consist of shale, sandstone, and siltstone. The shales are clayey to silty, locally bentonitic and gypsiferous, carbonaceous in part, firm to soft, earthy and crumbly, fissile or laminated to massive bedded, gray, dark gray, black, or brown. Slickensided fractures are common. The sandstones are fine-grained, silty, slightly clayey, limy, carbonaceous in part, laminated to massive bedded, soft to weakly cemented and friable, to locally moderately hard, light gray to gray or dark gray. The siltstones are clayey, fine sandy, carbonaceous in part, laminated to massive bedded, firm, gray to light gray. Hard ferruginous-cemented concretions up to 2 feet in diameter occur in the Kirtland Shale.

The Fruitland Formation consists predominantly of shale, sandstone, siltstone, and coal. Thin beds of limestone are reported in the geologic literature to occur from place to place in the lower part of the formation; however, none were cored in drill holes at the Bisti West study site. The formation was laid down in flood plain and swamp environments; consequently, most rock units are discontinuous. Individual beds

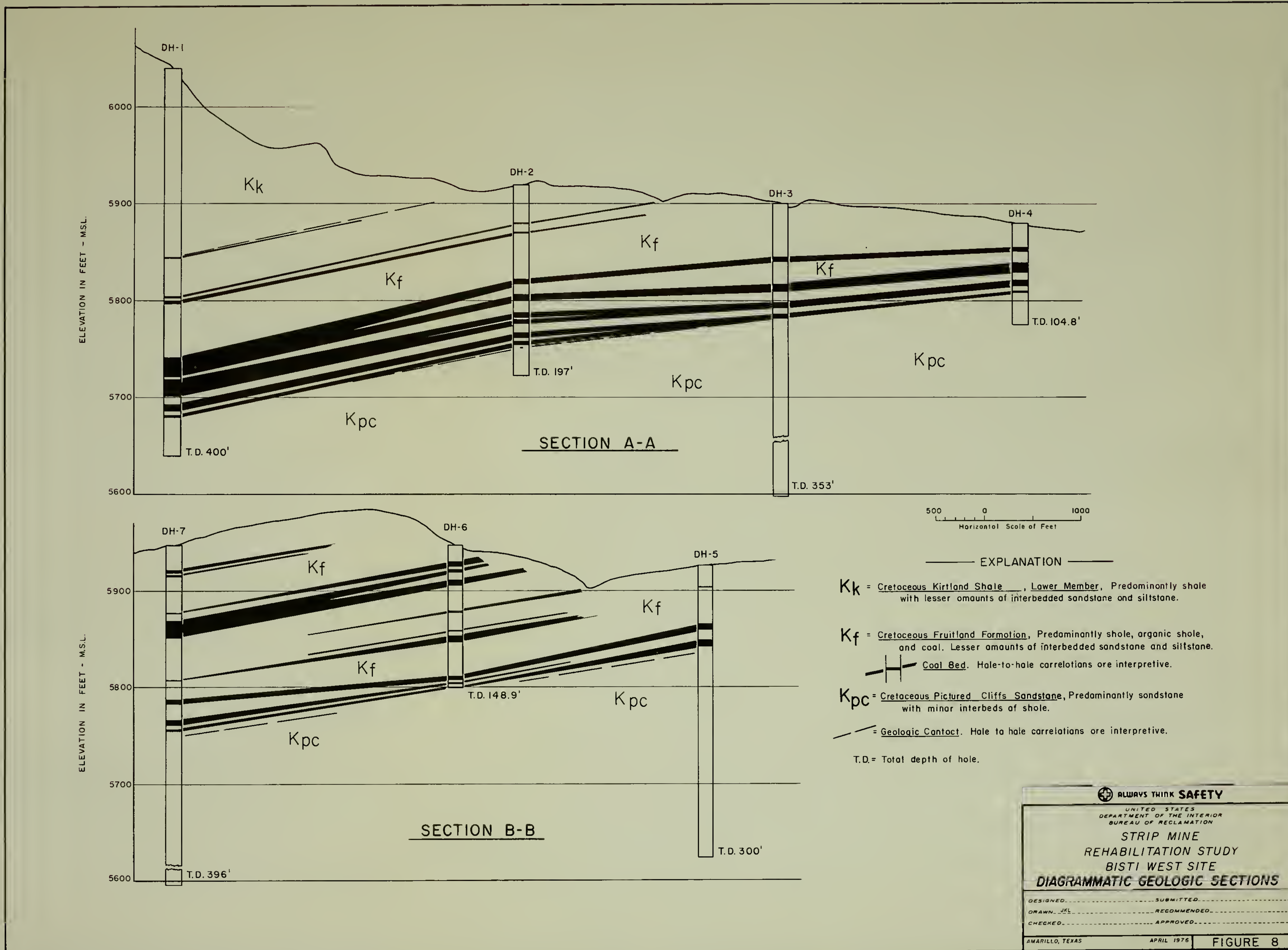
thicken, thin, and pinch out laterally, often within a few hundred feet. The coal beds are the most continuous lithologic units and in places can be traced for several miles. The coal beds are thicker and more numerous in the lower one-third of the formation. Sandstone is usually more abundant in the lower part of the formation, while shale and siltstone are more abundant in the upper part. Based on the geologic logs for DH-1 through DH-7, shale makes up an average of roughly 50 percent of the formation, coal about 25 percent, sandstone about 20 percent, and siltstone about 5 percent. A bed of bentonitic shale was cored in DH-1 between depths 282 and 287.6 feet.

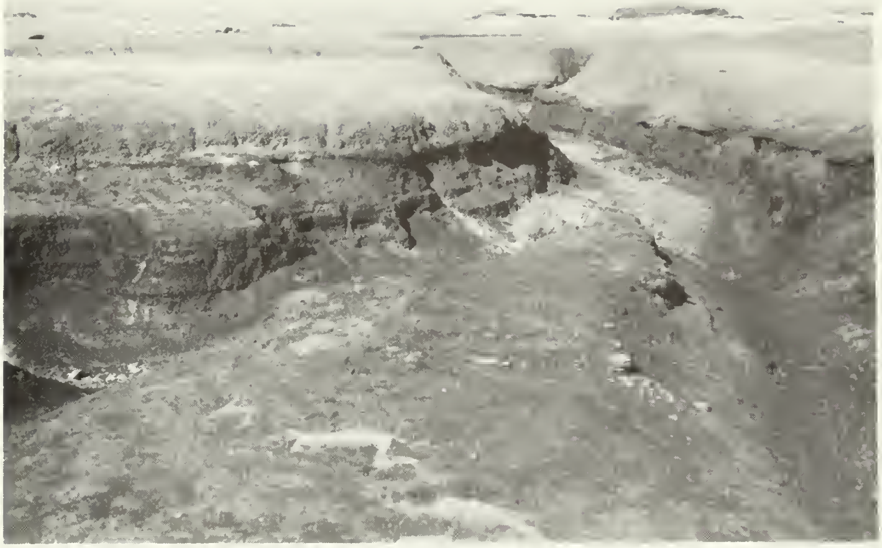
The contact of the Fruitland Formation with the overlying Kirtland Shale is arbitrarily placed at the top of the highest coal or carbonaceous bed. The Fruitland Formation was found to have the following thicknesses (feet): DH-7, 170.9; DH-1, 165.7; DH-6, 148.9; DH-2, 154.0. The upper part of the formation has been removed by erosion in the southern part of section 7, where the formation was found to be 56.4 feet thick at DH-4 and 86.9 feet thick at DH-3.

The Kirtland Formation in the San Juan Basin has been divided into three members--the lower shale, the Farmington sandstone or middle member, and the upper shale. Only the lower shale is evident in the study site area, where most of the formation has been removed by erosion or was not deposited. According to the defined contacts, the Kirtland was cored between depths 14.8 and 193.8 feet at DH-1, indicating a thickness of 179 feet beneath Alamo Mesa. The geologic log for DH-1 indicates the Kirtland consists of roughly 65 percent shale, 25 percent sandstone, and 10 percent siltstone.

Interpretive north-south stratigraphic hole-to-hole correlations of the various formational contacts and coal beds are shown on figure 8, Diagrammatic Geologic Sections.

Aquifers. No recognizable aquifers or other significant ground water bodies were noted during coring or during drilling operations which deepened DH-3, DH-5, and DH-7 to depths of 353, 300, and 396 feet respectively. Moreover, the generally fine-grained nature of the formation rock and lack of fracture or other types of permeability would generally preclude the presence of significant aquifers to the explored depths. Minor quantities of perched ground water occur in the Central Basin of the San Juan Basin in some areas in relatively shallow sandstone bodies. Low annual precipitation; high runoff; high evaporation; and terrain consisting of mesas, narrow ridges, high cliffs, and deep canyons usually limit infiltration to these bodies. No springs or seeps were noted in the study area. More discussion of ground-water-bearing units at the study site is in the Hydrology and Water Supply section of this chapter.


DH-1
DH-2
DH-3
DH-4
6000
5900
5800
5700
5600
ELEVATION IN FEET - MSL.
Kk
Kf
Kf
Kf
Kpc
Kpc
Kpc
T.D. 400'
T.D. 197'
T.D. 353'
T.D. 104.8'
SECTION A-A
500 0 1000
Horizontal Scale of Feet
DH-7
DH-6
DH-5
Kf
Kf
Kf
Kpc
Kpc
T.D. 148.9'
T.D. 396'
T.D. 300'
SECTION B-B
EXPLANATION
Kk = Cretaceous Kirtland Shale, Lower Member, Predominantly shale with lesser amounts of interbedded sandstone and siltstone.
Kf = Cretaceous Fruitland Formation, Predominantly shale, organic shale, and coal. Lesser amounts of interbedded sandstone and siltstone.
Coal Bed. Hole-to-hole correlations are interpretive.
Kpc = Cretaceous Pictured Cliffs Sandstone, Predominantly sandstone with minor interbeds of shale.
= Geologic Contact. Hole to hole correlations are interpretive.
T.D. = Total depth of hole.
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
STRIP MINE
REHABILITATION STUDY
BISTI WEST SITE
DIAGRAMMATIC GEOLOGIC SECTIONS
DESIGNED
SUBMITTED
DRAWN JKL
RECOMMENDED
CHECKED
APPROVED
AMARILLO, TEXAS
APRIL 1976
FIGURE 8



Coal outcrop (Fruitland formation) about one-half mile southwest of DH-5. Gully is about 8 feet deep and 10 to 20 feet wide. (2-76)

Looking upstream on De-Na-Zin Wash from 150 feet southeast of DH-4. (2-76)

Engineering geology. The shale, sandstone, and siltstone constituting overburden in the lower Kirtland Shale and overburden and material separating coal beds in the Fruitland Formation are similar in engineering properties. Rock in both formations is firm to only weakly cemented except for minor ferruginous-cemented concretions and thin beds. All excavation would be classed as common; however, blasting would facilitate excavation.

Excavations in the Kirtland Shale and Fruitland Formation would stand on near-vertical slopes for several months. Minor ravelling of slopes could be expected as the materials dry and air-slake. Stability of slopes is expected to decrease with the increased moisture of wet weather. (See Results of Weathering Tests, appendix B).

Haul roads surfaced with spoil material would be unusually slick and difficult to travel during periods of wet weather. Haul roads would be unusually soft during periods of alternate freezing and thawing, particularly in the spring, and would require continuous maintenance.

Coal Resources

For discussions of coal depths and thicknesses at the study site and coal origin, classification, rank, type, and grade, in general, see appendix E.

Most of the study site coal samples listed in table 3 show an apparent rank of subbituminous A. The ash and sulfur contents of 16 coal samples from the general area of the Bisti West study site, as-received, are: ash-range 11.2 to 42.8 percent, average 22.2 percent; sulfur range 0.4 to 0.9 percent, average 0.5 percent. The average as-received heat value is 8,078 Btu.

The coal of the Bisti West general area is in the lower 150 feet of the Upper Cretaceous Fruitland Formation. The Fruitland is a sequence of highly lenticular nonmarine claystones, silty and sandy shales, and soft crossbedded sandstones with coal; the overlying Kirtland Shale is of similar lithology but lacks coal. The Fruitland is underlain by the marine Pictured Cliffs Sandstone, also of Late Cretaceous age.

Coal resource estimates have been prepared for the Bisti West EMRIA study site using standard procedures, definitions, and criteria of the U.S. Geological Survey and U.S. Bureau of Mines established for making coal resource appraisals in the United States. The term "coal resources" as used in this report means the estimated quantity of coal in the ground in such form that economic extraction is currently or potentially feasible.

Table 3

Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Fruitland Coal (Cretaceous age), Bisti West EMRIA site, San Juan, Co., New Mexico

[All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash free. All analyses by Coal Analyses Section, U.S. Bureau of Mines, Pittsburg, Pa.]

SAMPLE	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed Carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Core sample, drill hole 6, unnamed bed, depth 133.8-138.4 feet, NE 1/4, NE 1/4, SW 1/4, sec. 8, T. 23 N., R. 12 W.														
D178925	A	20.9	31.0	36.9	11.2	6.3	51.9	1.1	29.1	0.4	9,280	0.02	0.17	0.21
	B	-	39.2	46.6	14.2	5.0	65.6	1.4	13.3	.5	11,730	.02	.21	.27
	C	-	45.7	54.3	-	5.8	76.4	1.6	15.6	.6	13,670	.03	.25	.31
Core sample, drill hole 6, unnamed bed, depth 141.9-142.8 feet and 146.3-147.5 feet, NE 1/4, NE 1/4, SW 1/4, sec. 8, T. 23 N., R. 12 W.														
D178926	A	17.4	27.7	26.6	28.3	5.4	41.2	0.9	23.7	0.5	7,310	0.02	0.12	0.33
	B	-	33.6	32.2	34.2	4.2	49.9	1.1	10.0	.6	8,850	.02	.14	.40
	C	-	51.0	49.0	-	6.3	75.9	1.6	15.3	.9	13,450	.03	.21	.61
Core sample, drill hole 5, unnamed bed, depth 57.1-64.0 feet, NE 1/4, NE 1/4, NW 1/4, sec. 17, T. 23 N., R. 12 W.														
D178928	A	17.2	31.6	39.4	11.8	6.0	55.1	1.2	25.5	0.4	9,700	0.02	0.06	0.36
	B	-	38.1	47.7	14.2	4.9	66.6	1.4	12.4	.5	11,720	.02	.07	.44
	C	-	44.5	55.5	-	5.7	77.6	1.6	14.5	.6	13,660	.03	.08	.51
Core sample, drill hole 5, unnamed bed, depth 74.8-81.0 feet, NE 1/4, NE 1/4, NW 1/4, sec. 17, T. 23 N., R. 12 W														
D178929	A	16.7	33.4	37.0	12.9	5.9	54.5	1.1	25.2	0.4	9,700	0.02	0.12	0.28
	B	-	40.1	44.5	15.4	4.9	65.5	1.4	12.3	.5	11,640	.02	.14	.33
	C	-	47.4	52.6	-	5.8	77.4	1.6	14.6	.6	13,770	.03	.17	.39

Table 3 (con.)

Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Ftuitland Coal (Cretaceous age), Bisti West EMRIA site, San Juan Co., New Mexico--Continued

SAMPLE	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed Carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Core sample, drill hole 1, unnamed bed, depth 238.7-241.7 feet, NE 1/4, SE 1/4, NW 1/4 sec. 6, T.23 N., R. 12 W.														
D177032	A	11.0	27.0	26.5	35.5	4.5	39.5	1.0	18.6	0.9	6,970	0.01	0.24	0.62
	B	-	30.3	29.8	39.9	3.7	44.4	1.1	9.9	1.0	7,830	.01	.27	.70
	C	-	50.4	49.6	-	6.1	73.9	1.9	16.5	1.6	13.020	.02	.45	1.16
Composite core sample, drill hole 1, depth 297.5-302.0 feet and 302.0-317.5 feet, NE 1/4, SE 1/4, NW 1/4, Sec. 6, T. 23 N., R. 12 W.														
D177033- D177034	A	17.9	29.5	32.3	20.3	5.7	46.9	1.0	25.7	0.4	8,260	0.01	0.02	0.42
	B	-	35.9	39.3	24.8	4.5	57.2	1.2	11.8	.5	10,060	.01	.02	.51
	C	-	47.7	52.3	-	5.9	76.0	1.6	15.8	.7	13,380	.01	.03	.68
Composite core sample, drill hole 1. depth 320.4-330.0 feet and 330.0-338.0 feet, NE 1/4, SE 1/4, NW 1/4, sec. 6, T. 23 N., R. 12 W.														
D177035- D177036	A	15.5	21.8	22.5	40.2	4.4	32.5	0.7	21.8	0.4	5,610	0.07	0.05	0.25
	B	-	25.8	26.7	47.5	3.2	38.5	.8	9.6	.4	6.640	.09	.05	.29
	C	-	49.1	50.9	-	6.1	73.3	1.5	18.3	.8	12,650	.16	.10	.56
Composite core sample, drill hole 1, depth 346.0-353.2 feet and 357.5-359.5 feet, NE 1/4, SE 1/4, NW 1/4, sec. 6, T. 23 N., R. 12 W.														
D177037- D177038	A	16.4	26.5	33.6	23.5	5.2	46.2	1.0	23.7	0.4	8,150	0.02	0.04	0.35
	B	-	31.7	40.2	28.1	4.0	55.3	1.2	10.9	0.5	9,750	.02	.05	.42
	C	-	44.1	55.9	-	5.6	76.9	1.7	15.1	.7	13,550	.03	.07	.58

Table 3 (con.)

Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Fruitland Coal (Cretaceous age), Bisti West EMRIA site, San Juan Co., New Mexico--Continued

SAMPLE	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed Carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Core sample, drill hole 3, unnamed bed, depth 81.8-89.5 feet, SE 1/4, SE 1/4, NW 1/4, sec. 7, T. 23 N., R. 12 W.														
D177040	A	20.4	29.0	36.9	13.7	6.0	51.0	1.1	27.8	0.4	8,870	0.02	0.03	0.37
	B	-	36.5	46.4	17.1	4.6	64.1	1.4	12.3	.5	11,140	.02	.04	.46
	C	-	44.0	56.0	-	5.6	77.4	1.7	14.7	.6	13,450	.03	.05	.56
Core sample, drill hole 3, unnamed bed, depth 100.0-105.5 feet, SE 1/4, SE 1/4, NW 1/4, sec. 7, T. 23 N., F. 12 W.														
D177041	A	22.3	27.9	35.0	14.8	6.0	48.4	0.9	29.5	0.4	8,440	0.01	0.06	0.35
	B	-	36.0	45.0	19.0	4.6	62.3	1.2	12.4	.5	10,860	.01	.08	.46
	C	-	44.4	55.6	-	5.6	77.0	1.5	15.2	.7	13,410	.01	.09	.56
Core sample, drill hole 3, unnamed bed, depth 113.7-116.9 feet, SE 1/4, SE 1/4, NW 1/4, sec. 7, T. 23 N., R. 12 W.														
D177042	A	25.0	28.5	33.3	13.2	6.3	48.1	0.6	31.4	0.4	8,390	0.01	0.02	0.39
	B	-	38.0	44.4	17.6	4.7	64.0	.9	12.2	.6	11,180	.01	.02	.53
	C	-	46.2	53.8	-	5.8	77.8	1.1	14.6	.7	13,580	.01	.03	.64
Core sample, drill hole 4, unnamed bed, depth 40.3-48.0 feet, SW 1/4, SE 1/4, SW 1/4, sec. 7, T. 23 N, R. 12 W.														
D177043	A	17.4	30.2	39.2	13.2	5.9	54.1	1.2	25.1	0.5	9,340	0.13	0.05	0.29
	B	-	36.5	47.5	16.0	4.8	65.5	1.4	11.7	.6	11,310	.15	.07	.35
	C	-	43.5	56.5	-	5.7	78.0	1.7	13.9	.7	13,460	.18	.08	.42

Table 3 (con.)

Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Fruitland Coal (Cretaceous age), Bisti West EMRIA site, San Juan Co., New Mexico--Continued

SAMPLE	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed Carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Core sample, drill hole 4, unnamed bed, depth 60.3-64.9 feet, SW 1/4, SE 1/4, SW 1/4, sec. 7, T. 23 N., R. 12 W.														
D177044	A	14.5	30.9	36.5	18.1	5.4	51.4	1.1	23.5	0.5	9,050	0.11	0.04	0.33
	B	-	36.2	42.6	21.2	4.4	60.2	1.3	12.3	.6	10,580	.13	.04	.38
	C	-	45.9	54.1	-	5.6	76.4	1.6	15.7	.7	13,430	.17	.06	.49
Core sample, drill hole 4, unnamed bed, depth 69.2-71.4 feet, SW 1/4. SE 1/4, SW 1/4, sec. 7, T. 23 N., R. 12 W.														
D177045	A	11.1	25.5	24.6	38.8	4.3	37.5	0.8	18.2	0.4	6,640	0.12	0.02	0.26
	B	-	28.7	27.6	43.7	3.5	42.2	.9	9.3	.4	7,470	.14	.02	.29
	C	-	51.0	49.0	-	6.2	74.9	1.5	16.6	.8	13,270	.25	.04	.51
Core sample, drill hole 7, unnamed bed, depth 30.6-32.0 feet, NE 1/4, NE 1/4, NW 1/4, sec. 8, T. 23 N., R. 12 W.														
D177046	A	16.1	22.7	18.4	42.8	4.5	29.7	0.6	21.8	0.8	5,200	0.10	0.25	0.43
	B	-	27.0	21.9	51.1	3.1	35.4	.7	8.8	.9	6,200	.12	.30	.51
	C	-	55.2	44.8	-	6.3	72.3	1.4	18.1	1.9	12,670	.24	.61	1.05
Composite core sample, drill hole 7, unnamed bed, depth 78.4-87.0 feet and 87.4-94.7 feet, NE 1/4, NE 1/4, NW 1/4, sec. 8, T. 23 N. R. 12 W.														
D177047-D177048	A	21.7	29.6	32.6	16.1	6.0	47.7	0.9	28.9	0.4	8,340	0.02	0.03	0.38
	B	-	37.8	41.7	20.5	4.6	61.0	1.2	12.2	.5	10,660	.02	.04	.48
	C	-	47.5	52.5	-	5.7	76.7	1.5	15.4	.7	13,420	.03	.05	.61

Tables 4, E-1 */, and E-2 summarize the estimated coal resources of the Bisti West EMRIA study site (about 4 square miles), and of a larger area (about 6 square miles) that is composed of the EMRIA site proper and adjoining areas. Table E-2 lists the estimated resources of the area in a more detailed form. The resources in the study site are classed as measured, indicated, and inferred according to the degree of geologic assurance of the estimate.

Three categories according to degree of geologic assurance were used in the present study.

1. Measured - Resources are computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes. The points of observation and measurement are so closely spaced and the thickness and extent of coals are so well defined that the tonnage is judged to be accurate within 20 percent of true tonnage. Although the spacing of the points of observation necessary to demonstrate continuity of the coal differ from region to region according to the character of the coal beds, the points of observation are no greater than 1/2 mile (.8 km) apart. Measured coal is projected to extend as a 1/4-mile- (.4 km) wide belt from the outcrop or points of observation or measurement.

2. Indicated - Resources are computed partly from specific measurements and partly from projections of visible data for a reasonable distance on the basis of geologic evidence. The points of observation are 1/2 (.8 km) to 1-1/2 miles (2.4 km) apart. Indicated coal is projected to extend as a 1/2-mile- (.8 km) wide belt that lies more than 1/4 mile (.4 km) from the outcrop or points of observation or measurement.

3. Inferred - Quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region and where few measurements of bed thickness are available. The estimates are based primarily on an assumed continuation from measured and indicated coal for which there is geologic evidence. The points of observation are 1-1/2 (2.4 km) to 6 miles (9.6 km) apart. Inferred coal is projected to extend as a 2-1/4-mile- (3.6 km) wide belt that lies more than 3/4 mile (1.2 km) from the outcrop or points of observation or measurement.

All of the estimated resources in beds thicker than 5 feet and at depths of 1,000 feet or less fall into a category called reserve base, which is defined as that portion of the identified coal resource from which reserves are calculated. Reserves are that part of the identified coal resource that can be economically mined at the time of determination. The reserve is derived by applying a recovery factor to that component of the identified coal resource designated as the reserve base. On a national basis the estimated recovery factor for the total reserve base

*/ Table and figure numbers prefixed with upper case letters identify appendix materials.

Table 4
Summary of estimated identified coal resources of Bisti West EMRIA site

[In thousands of tons]

	Overburden thickness (feet)			
	0-200	200-1,000	More than 1,000	Total
Coal beds 2½ to 5 feet thick				
Measured resources	4,556	317	-	4,873
Indicated resources	7,770	391	-	8,161
Inferred resources	-----	---	-	-----
Total	12,326	708	-	13,034
Coal beds 5 to 10 feet thick				
Measured resources	14,281	1,830	-	16,111
Indicated resources	30,615	5,813	-	36,428
Inferred resources	4,542	-----	-	4,542
Total	49,438	7,643	-	57,081
Coal beds more than 10 feet thick				
Measured resources	6,532	7,903	-	14,435
Indicated resources	11,258	16,365	-	27,623
Inferred resources	1,643	------	-	1,643
Total	19,433	24,268	-	43,701
Total identified resources	81,197	32,619	-	113,816

is 50 percent. More precise recovery factors can be computed by determining the total coal in place and the total coal recoverable in any specific locale.

The coal characteristics that are commonly used in classifying coal resources are the rank, grade, and weight of the coal; the thickness of coal beds; and the thickness of the overburden. Rank and grade are discussed in appendix E.

The weight of the coal ranges considerably with differences in rank and ash content. In areas such as Bisti West where true specific gravities of the coal have not been determined, an average specific gravity value based on many determinations in other areas is used to express the weight of the coal for resource calculations. The average weight of subbituminous coal is taken as 1,770 tons per acre-foot (a specific gravity of 1.30).

Thicknesses of beds and overburden

Because of the important relationship of coalbed thickness to utilization potential, most coal resource estimates prepared by the U.S. Geological Survey are tabulated according to three thickness categories. For subbituminous coal, the categories are: thin, 2.5 to 5 feet (0.75 to 1.5 m); intermediate, 5 to 10 feet (1.5 to 3 m); and thick, more than 10 feet (3 m). About 12 percent of the estimated resources of the study area is in the thin category, about 48 percent is in the intermediate category, and about 40 percent is in the thick category. By way of comparison, Averitt (1975, Figure 5 and page 37) shows the distribution of the estimated resources of 21 states as 42 percent in the thin category, 25 percent in the intermediate category, and 33 percent in the thick category. In the EMRIA site proper, about 12 percent of the estimated resources is in the thin category, about 50 percent is in the intermediate category, and about 38 percent is in the thick category.

About 71 percent of the estimated coal resources in the Bisti West EMRIA site is overlain by 200 feet (60 m) or less of overburden.

Summary of resources

Total estimated identified original resources in the Bisti West EMRIA site and adjoining area is 174,443,000 tons. Coalbeds 2.5 to 5 feet thick contain 20,018,000 tons. Coalbeds from 5 to 10 feet thick make up 83,755,000 tons of the estimated resources, and beds more than 10 feet thick make up 70,670,000 tons.

The estimated identified original resources with 200 feet or less of overburden in the Bisti West EMRIA site and adjoining area total 108,917,000 tons, of which 28,389,000 tons are classed as measured, 65,994,000 tons

as indicated, and 14,534,000 tons as inferred resources. Beds more than 10 feet thick make up 33,687,000 tons of the estimated resources with 200 feet or less of overburden.

In the EMRIA site the estimated identified original coal resources with 200 feet or less of overburden total 81,197,000 tons. Coalbeds from 2.5 to 5 feet thick make up 12,326,000 tons, coalbeds from 5 to 10 feet thick make up 49,438,000 tons, and beds more than 10 feet thick make up 19,433,000 tons.

The estimated resources presented in this report are original resources, that is, resources in the ground before the beginning of mining operations.

Major, minor, and trace-element composition

Twenty samples of coalbeds in the Bisti West study site were subjected by the U.S. Bureau of Mines, Pittsburgh, Pa., to proximate analysis for percent moisture, volatile matter, fixed carbon, and ash and ultimate analysis for percent hydrogen, carbon, nitrogen, oxygen, and sulfur. The ash content of the coals (as-received basis) ranges from 13.2 to 42.8 percent and averages 22.6 percent; the sulfur content ranges from 0.4 to 0.9 percent and averages 0.5 percent; and the Btu/lb ranges from 5,200 to 9,340 and averages 7,980.

Forty samples of coalbeds from the Bisti West study site were analyzed for the following constituents:

(1) Major composition of the ash of coal-percent ash, SiO_2, Al_2O_3, Na_2O, K_2O, CaO, MgO, Fe_2O_3, P_2O_5, Cl, MnO, TiO_2, and SO_3.

(2) Trace element composition of coal
   a. Individual quantitative determinations--p/m As, Cd, Cu, F, Hg, Li, Pb, Sb, Se, Th, U, and Zn.
   b. Semiquantitative spectrographic analysis--p/m of 20-30 elements detected by this method.

Results of the analytical determinations are listed in tables E-3, E-4, E-5, and E-6.

Table E-4 compares analyses of 40 coal analyses from the Bisti West study site with 79 other samples from the San Juan River region (Hatch and Swanson 1976).

Table 5 shows the range of and average elemental content on the whole-coal basis of those constituents commonly regarded as being of importance from the standpoint of coal utilization. Some of the elements, such as mercury and arsenic, are of interest because of the environmental problems that might occur if they are present in inordinate amounts; others such

Table 5
Elements that can affect potential utilization of coals--content in 40 samples from the Bisti West study site

	Range p/m	Average p/m	Average continental crust p/m (Taylor, 1964)
As	0.5 - 32	2	1.8
Cd	.4 L- .4	---	0.2
Cu	5.8 - 34.3	14.5	55
F	20 L-145	71	625
Hg	.01 - .26	.07	.08
Li	7.0 - 39.7	20.4	20
Pb	6.8 - 25.7	12.9	12.5
Sb	.3 - 6.5	1.3	.2
Se	.6 - 3.0	1.7	.05
Th	3.0 L- 24.8	9.7	9.6
U	1 - 9.4	3.2	2.7
Zn	4.5 - 47.7	19.3	70
B	50 -150	70	10
Be	1.5 - 15	5	2.8
Ni	1.5 - 15	5	70
Zr	3 -200	70	165

as uranium and thorium are of interest because they could be recovered from coal ash if they are present in sufficiently large quantities. Based on the 22.6 percent average ash content of the Bisti West study site coal, trace elements such as uranium and thorium will be enriched in the ash approximately five times their whole coal value.

In comparing the arithmetic mean of elements listed in table 5 with an average value of these elements in the continental crust (Taylor 1964), only selenium (average value 1.7 p/m compared to 0.05 p/m average crustal abundance), antimony (average value 1.3 p/m compared to 0.2 p/m average crustal abundance), and boron (average value about 70 p/m compared to 10 p/m average crustal abundance) are higher in the study site coal by more than a factor of five. Fluorine and nickel are depleted in the Bisti West coal by more than a factor of five when compared to the average crustal abundance of these elements. The other trace elements are present in amounts that approximate their abundances in the continental crust.

Soil and Bedrock Material

Major land categories

The four major land categories encompassing the landforms and soil bodies of the study site are mesas (about 16 percent of the study site), valleys (44 percent), badlands (30 percent), and miscellaneous (10 percent). Figure 3 shows the approximate location and distribution of the categories (figures B-5 to B-8 show the categories in detail).

Mesas. This category is dominated by mesas but also includes elevated benches and sandy ridges. The topography is gently sloping, slightly undulating, or, infrequently, very gently rolling. The soils formed mainly from thick alluvial deposits on ancient stream terraces or alluvial fans. Geologic erosion wore away adjacent areas of the original landscape, leaving lands of this category elevated. This category of land supports some of the best vegetation at the study site.

Soil above bedrock is usually 60 inches or more deep. Surface soils range from fine sand to loam. Colors are pale brown, light yellowish brown, brown, or light brownish gray. Structure is usually single grain, granular, or massive. Subsoils range from fine sand to clay loam. Colors are usually pale brown, light yellowish brown, or light brownish gray. Structure is mostly single grain, fine granular, or massive.

Generally soil permeability is moderately rapid to rapid and water-holding capacity is relatively low. Soils are generally nonsaline and nonsodic. No harmful accumulations of other chemicals were detected. On the more pronounced mesas, however, accumulations of calcium carbonate are generally present in the subsoil. Although having some deficient

Looking northwest from near AH-9. Foreground is vegetated sandy ridge (Class 2); middle ground is barren saline-sodic area (Class 6); just beyond is desert pavement and very shallow aeolian deposits supporting sparse vegetation (Class 6); background is badlands and Alamo Mesa. (4-76)

Looking north from near AH-21. Desert pavement (Class 6) in foreground; very shallow aeolian deposits (Class 3) supporting vegetation in middle ground; badlands in background. (4-76)

soils, most of this land category is suitable as a source of planting media (see Land Suitability, Chapter II, for definition of suitable and unsuitable planting media).

Soil profiles 1, 3, 7, 51, 70, and 75 (figures B-1 to B-4) are representative of these lands. The dominant soil series are Shiprock, Sheppard, Grandview, Doak, and Mayqueen. (See Soil Inventory, Chapter II, for more information on soil series at the study site.)

Valleys. Valley lands at the study site have a wide range of characteristics. Depth to bedrock varies from 0 to 15 feet. Much valley land with bedrock 60 inches or less below the surface lies near the badlands. Small areas of rock outcrop at various stages of weathering are scattered throughout valley lands. Valley lands were divided into two groups--sandy (v) (about 10 percent of study site) and saline-sodic (s-a) (34 percent).

Sandy--Twenty-two percent of valley lands are covered by relatively shallow depths of eolian materials overlying saline-sodic deposits. Topography of these lands is usually nearly level or gently sloping, but some areas are undulating and some have blowouts. These lands support some vegetation, including coppice mounds (small mounds of soil material stabilized around vegetation).

Total depth of surface and subsurface soils ranges from a few inches to more than 60 inches. Surface soils range from sand to sandy loam. Colors are light yellowish brown, light brown, or pale brown. Structure is usually single grain or granular. Subsoils are usually coarse textured ranging from sand to sandy loam; however, some loam and clay loams are present. Color of the subsoil is light yellowish brown, pale brown, light brown, brown, or grayish brown. The sandy subsoil structure is usually single grain or granular and in some places compact. The loam and clay loam subsoils are usually granular or fine blocky.

Permeability of the sandy material overlying the alluvial deposits is usually moderately rapid to rapid. However, moisture penetration into the underlying part of the profile, where finer textures usually occur, is usually very slow. In some cases where coarse textures occur, laboratory analysis of disturbed samples indicates permeability is zero (tables B-5 and B-9). Available moisture capacity in surface soils is relatively low but, under management, is adequate to maintain vegetation.

Except for sodicity in a few isolated spots, most of the surface soils and sandy subsoils have no harmful accumulations of salinity or exchangeable sodium. The underlying finer textured materials, however, are usually saline-sodic. They have very restricted permeability, are unstable, and will swell.

Looking southeast from near AH-21. Most of area shown is desert pavement and other Class 6 land. Picture illustrates general flatness of study site valley lands. (4-76)

Corral and ruins of old trading post (outside of study site) 2,000 feet southwest of AH-4. Corral used by local rancher who uses study site for grazing purposes. (8-75)

Although having major deficiencies, soils of this group are suitable for use as planting media for reclamation purposes. Because they are subject to severe wind erosion, are highly permeable, and tend to lack adequate water holding capacity, they must be specially managed after disturbance and during stockpiling and seeding.

Soil profiles 13, 20, 23, 24, and 48 (figures B-1 to B-3) are representative of these lands. The dominant soil series are Sheppard, Shiprock, Doak, and Fruitland.

Saline-sodic--These lands are characterized by soils with excessive salinity or sodicity or both. Scattered throughout these lands are patches of desert pavement (very thin layers of gravel or stones left on the land surface after removal of fines by wind action), slick spots (small areas slick when wet due to a high content of exchangeable sodium), and crusts (usually 1/4 to 1-1/2 inches thick). Saline-sodic lands are nearly level or very gently sloping and dissected by drainageways and rills. Except for very shallow (6 to 12 inches thick) sandy eolian material on scattered areas, soils have developed from alluvial material. Near the badlands, on the upland valley slopes, are areas of local alluvium over residual geologic material. Soils are usually barren or have scattered sparse vegetation. Thicker vegetation grows, however, in the eolian material. Coppice mounds also occur.

Most of the soils on the upland valley slopes, near the badlands, are shallow, usually 6 to 36 inches deep, over weathered shale and sandstone. The depths of the nearly level valley areas are usually greater than 60 inches, although soils less than 36 inches deep (and rock outcrops) occur in section 7. Weathered coal seams were encountered at various shallow depths, usually between the upland valley slopes and the nearly level valley land.

Textures of surface soils range from loamy sand to clay. Colors are usually light yellowish brown, pale brown, brown, light brownish gray, grayish brown, or dark grayish brown. Structures are usually single grain or granular. Subsoil and substratum textures range from sand to clay. Colors are usually light yellowish brown, pale brown, brown, light brownish gray, or dark grayish brown. Structures are usually single grain, massive, or blocky.

Field observations and laboratory analysis indicate that permeability varies (tables B-5 and B-9). Some of the surface and subsurface materials have sufficient moisture penetration for use as planting media. Where a high amount of sodic material occurs, however, a sealing effect takes place that prevents virtually any moisture penetration. These highly sodic soils are therefore generally unsatisfactory for use as planting media.

Looking northeast from near center Section 17 at outcrops composed of beds of shale and coal. Although composed of local weathered material (Class 6), the flat area supports sparse vegetation because it accumulates some moisture. (4-76)

Looking southeast from near AH-46 at typical barren saline-sodic soil (Class 6). Just beyond are very shallow aeolian deposits (Class 6) supporting some vegetation. (4-76)

Looking northwest from near AH-21. Desert pavement and other Class 6 land in most of picture; badlands and Alamo Mesa in background. (4-76)

Looking northeast from near AH-21. Coppice mounds in foreground; just beyond are scattered areas of desert pavement and shallow, vegetated aeolian deposits; badlands in background. (4-76)

Soils with salinity exceeding the specifications for suitable planting media exist throughout these lands.

The best source of planting media is the sandy eolian material. Other sources of suitable material may be obtained from soil layers of acceptable quality (see table B-5). Most of the saline-sodic soils are unsuitable as a source for planting media in their present condition. It may be possible, however, to improve some of these soils by mixing them with good quality media or with additives if additional soil for revegetation is absolutely necessary.

Profiles 22, 25, 35, 37, 38, 44, 65, and 66 (figures B-1 to B-3) are representative of these lands. The dominant soil series are Uffens, Turley, Huerfano, Stumble, Laton, Fruitland, Azfield, and Doak.

Badlands. Some of these lands are rough and steep or very steep, especially near the mesas, and have numerous intermittent drainage channels entrenched in soft shale and sandstone. Generally, badland surfaces consist of weathered shale and sandstone. Sandstone-capped pedestals occur in some places. Almost all of the badlands are barren, although a few spots of very sparse vegetation occur.

Although little or no soil development has occurred, fine textured, usually heavy, alluvial soils are usually present at or near the base of slopes. These soils are shallow, usually 2 to 12 inches deep, with textures ranging from sandy loam to clay and generally mixed. Colors are grayish brown, dark grayish brown, brown, or mottled, the last especially just above the shale or sandstone. Structure is usually blocky or granular.

Because of their high erosion hazard, very slow or no permeability, shallow depth, low natural fertility, strong sodicity, and excess salinity, the soils will provide little or no planting media. It may be desirable in a revegetation program to consider the use of some of these soils, however, after mixing them with better quality soils or treating them with additives to improve structure stability.

Soil profiles 69 and 71 (figures B-4 and B-1) are representative of these lands where soil development has occurred. The dominant soil series are usually phases and variations of Huerfano, Uffans, Turley, Stumble, and Sheppard.

Miscellaneous. This category includes three groups--active dunes, hummocky areas, and stream channels.

Active dunes--Most of these lands consist of undulating land and small hills. Slopes vary widely, and local relief is 5 to 20 feet. Vegetation near the dune margins is sparse. Active dunes consist of sandy eolian deposits 60 inches or more in depth. The nature of surface

Looking northeast at badlands 900 feet southwest of AH-10. Note pedestals. Weathered shale and sandstone (Class 6) in foreground. (8-75)

Closeup view, looking north, of badlands 1,000 feet southwest of AH-2. Picture illustrates extreme saline-sodic condition of study site badlands. Gully is about 8 feet deep. Alamo Mesa in background. (8-75)

layers varies, depending on the eroded parent material. Generally, textures range from fine sand to sand. Colors are usually light brown, pale brown, brown, or light yellowish brown. The structure is single grain.

Permeability is very rapid, and available water holding capacity is very low. Stability is critical because of high susceptibility to wind erosion. These soils are considered unsuitable for planting media.

Soil profile 78 (figure B-2) is representative of the active dunes. The soil of the vegetated areas is a coarse-textured phase of Sheppard.

Hummocky areas--These are undulating lands with slopes from 0 to 20 percent. Small blowouts are scattered throughout. Vegetation, mostly greasewood, covers nearly the entire area. Soils are derived from sandy eolian deposits, but alluvial material in the substratum is possible, especially near De-Na-Zin Wash.

Soil depth is usually 60 inches or more. Soils north of De-Na-Zin Wash have scattered rock outcrops, weathered shales, and sandstones at various depths. Surface soil texture is usually loose fine sand or loamy fine sand. Colors are brown, light brown, or light yellowish brown. Structure is usually single grain but is sometimes slightly cemented, especially the surface 1 or 2 inches. Subsoil texture is usually fine sand, loamy fine sand, or sandy clay. Colors include brown, light brown, or light yellowish brown. Structure is usually single grain and sometimes cemented. Finer textured subsoils usually have an angular blocky structure.

Permeability is very rapid, and available water holding capacity is low. These soils are sodic at the surface in certain locations, especially in section 8, where crusting and cementation are more pronounced. The condition of surrounding soils indicate that some saline-sodic areas can be expected in hummocky lands.

The fact that these soils presently support vegetation argues that they could be considered as a source of material for a planting media. Indeed, the hummocky soils in sections 7 and 17 are suitable for planting media (according to the criteria). Because of their coarse textures, however, special care must be taken to prevent severe wind erosion. The areas in section 8 were classed as unsuitable because of sodicity, coarse textures, and cemented surface conditions.

Soil profiles 73 and 77 (figure B-3) are representative of hummocky lands. The soils consist of various phases of the Sheppard series, such as stabilized dunes, rock outcrops (shale, sandstone, and coal), coarse-textured shallow phases, and saline-sodic phases.

Stream channels--This group consists of fluvial deposits in De-Na-Zin Wash and Coal Creek. Random shallow deposits of eolian material

also occur. The stream channels are almost barren, except where enough time elapsed since the previous flood to allow the growth of temporary vegetation.

Depth is 60 inches or more. Textures are usually sandy, with some deposits of gravel and cobble. Colors are usually brown, light brown, or light yellowish brown. Structure is single grain.

Flooded whenever runoff occurs, stream channel materials are generally moist to very moist. If transported from the confines of the channels, these materials would dry out very quickly because of their very low available water holding capacity. These coarse-textured materials are subject to severe wind erosion if dry.

Use of fluvents for suitable planting media may be difficult. Their major limitations are combinations of instability, susceptibility to erosion, coarse texture, very low available water holding capacity, and very low fertility.

Profile 72 (figure B-3) is representative of these soils. Fluvents consist of many closely related materials that cannot be separated into specific soil series. They are deep, generally stratified, and widely varied in texture.

Land suitability

Study site lands were surveyed and evaluated in order to classify them for their suitability as a source of material (planting media) for resurfacing the study site for revegetation (if surface-mined). The survey provided data on the quality, quantity, and ease of stripping and stockpiling planting media, and on other factors which affect suitability of the lands as a source of planting media.

Specifications were developed to enable this classification of study site lands for their suitability as a source of planting media. The specifications are the characteristics of the four land suitability classes--1, 2, 3, and 6--established for the study site. The class numbers correspond to those in the Bureau of Reclamation's classification system. The specifications include quality considerations such as texture, salinity, sodicity, permeability, infiltration capacity, available water holding capacity, and erodibility. The main quantity consideration was depth of suitable material. Stripping and stockpiling considerations included indurated bedrock exposures and excessive slope. The specifications are shown in table 6.

Class 1 lands, the best source of planting media, should supply a large amount of highly suitable material relatively easy to stockpile. If not surface mined (due to depth of coal), Class 1 lands could probably be a borrow area for resurfacing areas with insufficient planting media.

Table 6
LAND CLASSIFICATION SPECIFICATIONS 1/
Suitability of Surface Materials for Revegetation of Surface-mined Areas
BLM-BR Cooperative Program
Bisti West Study Site - New Mexico

	Land Class 1	Land Class 2	Land Class 3
Soils 2/			
Texture	lfs - cl	ls - c	fs - c
Available water holding capacity	> 1.5"/ft	> 1.0"/ft	> 0.75"/ft
Permeability (Internal drainage)	Adequate to provide a well-drained and aerated root zone and an infiltration rate adequate to prevent serious erosion	Slightly restricted which may result in some restriction of drainage and aeration in the root zone and a reduced infiltration rate	Restricted to the extent that internal drainage may limit choice of vegetation and require special practices to control erosion
Salinity (at equilibrium)	< 4 millimhos	< 8 millimhos	< 12 millimhos
Sodicity (at equilibrium)	< 10 ESP - may be higher if hydraulic conductivity meets limits for Class 1	< 10 ESP - may be higher if hydraulic conductivity meets limits for Class 2	< 15 ESP - may be higher if hydraulic conductivity meets limits for Class 3
Erodability	Subject to slight erosion	Susceptible to moderate erosion	Susceptible to severe erosion but can be controlled with proper management
Weatherability 3/	Will break down readily upon exposure to the weather	May require short period to break down upon exposure	May require extended period to break down into optimum particle size distribution but can be used in less desirable state in reasonable time period
Depth	> 36" of usable and strippable material	> 24" of usable and strippable material	> 6" of usable and strippable material 4/
Topography 5/			
Slope	< 20 percent	< 20 percent	< 25 percent
Surface rocks	Not a factor on the Bisti West site		
Bedrock outcrop	Will not affect stripping or quantity of suitable material	Numerous enough to reduce quantity of suitable material slightly and make stripping more expensive	Numerous enough to reduce quantity of suitable material appreciably and make stripping expensive

Drainage — Because of land alterations by surface-mining, present drainage conditions, excepting the permeability of the material, are not a factor in the classification. Permeability limits are covered under Soils.

Class 6 - All areas not meeting the minimum requirements for Classes 1, 2, or 3. These lands are unsuited as a source of material for revegetation.

1/ Specifications are based on rainfed conditions or a minimum of irrigation for starting plantings and maintenance through dry periods.
2/ The limitations under Soils are applicable to the evaluation of both soil and the overburden material between the coal and soil.
3/ Weatherability is applicable only to bedrock or unconsolidated material.
4/ Six inches is considered as the minimum strippable depth.
5/ Topographic factors considered are related primarily to stripping operations.

Class 2 lands have planting media, but they are of lower quality, difficult and expensive to handle, and limited in quantity.

Class 3 lands are similar to Class 2 lands except that deficiencies are greater or combined. Although marginally suitable, these lands can provide planting media under normal conditions and good handling management.

Class 6 lands generally do not have suitable or sufficient planting media. Disturbance of these lands by surface mining or other operations will require, if the lands are to be revegetated, that planting media be borrowed or Class 6 materials be processed to provide planting media.

Procedures. Study site lands were evaluated for suitability for revegetation following surface mining. Physical and chemical soil characteristics, topography, and drainage were considered. Land forms were examined in sufficient detail to determine their character and extent. Field observations were confirmed by laboratory tests of representative soil profile samples.

Land classes and mapping units (see Soil Inventory, Chapter II) were delineated in the field on aerial photographs (1" = 400'). Geological Survey (GS) quadrangle, 7.5-minute series, topographic maps (1:24,000) with 20-foot contour intervals were used for location and reference when mapping the land.

Most soils were bored, examined, sampled, and recorded to 10 feet. However, many borings were limited to less than 10 feet by the shale or sandstone underlying much of the area. Additional soils were examined to determine texture and depth to barrier (bedrock). All soil profiles were located and recorded on the aerial photos (see figures B-1 through B-4 for profile locations, descriptions, and land classification).

A tile spade was used to examine the surface layers (topsoil). The lower soil profile was exposed for examination and sampling with a truck-mounted power soil auger.

Genetic soil horizons and the underlying substratum were studied in detail. Color, structure, texture, consistency, and soil moisture relationships (such as permeability and water holding capacity) were observed, the last being the primary concern. The number and location of soil samples selected for laboratory analysis and greenhouse studies varied according to the particular conditions of the area.

A soils laboratory was extensively used to confirm the land classification done in the field. Screening tests were made on all soil and bedrock samples. Additional tests were made when more data were needed to support classification (see Laboratory Procedures, appendix B).

Truck-mounted soil auger used to obtain soil samples. Picture taken at AH-70 looking southeast. Soils and vegetation similar to Class 3 land on Alamo Mesa. (8-75)

Augering completed at AH-4. Soil profile (Class 6) laid out in one-foot increments. This profile had five feet of weathered coal. (8-75)

Many areas assigned certain classes may contain small amounts of soils of other classes, primarily near area margins, where classes often grade into others. Because the soils in each of the classes 2 through 6 have deficiencies, each class is divided into subclasses equivalent to certain deficiencies or combinations of deficiencies. Table 7 describes the characteristics of the classes and major subclasses.

The land classification symbols (figures 10 and 11) describe the entire soil profile. Because areal projection of soil profiles based on test holes is less accurate below 36 inches, only the soil above this depth was considered in determining the land class. Table 7 presents this evaluation.

Summary of land classification results. The Bisti West study site has material suitable for use as planting media in a revegetation program.

Class 1 lands (2 percent of study site) are located on Alamo Mesa. Soils are generally medium to coarse textured and deep. They have no harmful accumulations of soluble soils or sodium and are permeable. Topographic features will not hinder stripping.

Class 2 lands (8 percent of study site) are located on mesas, sandy ridges, and in the valleys. Soils are generally medium to coarse textured and shallow to deep. They have no large amounts of salinity or sodium and have good permeability. Topography will not hinder stripping.

Class 3 lands (19 percent of study site) are located throughout the study site. Soils are fine to coarse textured and shallow to deep. They have some harmful accumulations of salinity and sodium and rapid to very restricted permeability. Topography will not hinder stripping.

Class 6 lands (71 percent of study site) are located in all areas of the study site. Soils are fine to coarse textured and shallow to deep. They have harmful accumulations of salinity and sodium and very rapid to very limited permeability. Bedrock outcrops occur. Topography will hinder stripping.

The location of these classes is shown on figure 9; the location of the classes and subclasses is shown on figure 11. The following is a tabulation of land class acreages:

	Sec. 6	Sec. 7	Sec. 8	Sec. 17	Total
Class 1	56	0	0	0	56
Class 2	2	38	108	45	193
Class 3	131	161	51	93	436
Subtotal	189	189	159	148	685
Class 6	451	411	401	372	1,635
Indian Trust Land	0	40	80	120	240
Grand total	640	640	640	640	2,560

Table 7

Land Class and Major Subclass Characteristics 1/

Bisti West Study Site

Land classes and subclasses 2/	Approximate Acres	Major Chemical deficiency	Major Physical deficiency	Important Soil and Land Characteristics	Suitability, stockpiling, placement, and management characteristics
All classes				All soil overburden can be stripped easily. Topography will not hinder reclamation, except on class 6st/ -apg	Strip, transport, and stockpile carefully to prevent unplanned mixing. Mix soils carefully, as necessary, to improve poorer soils. Prevent poorer soils from directly or indirectly contaminating better soils. Protect from erosion during and after stockpiling and (as applicable) after revegetation. Protect revegetated areas from grazing until vegetation is well established.
1	56	None	None	Soils are deep; are coarser below 6 feet; have good permeability, adequate water holding capacity, some susceptibility to wind erosion; and are nonsaline and nonsodic.	Lands are best source of planting media. Manage revegetated areas normally.
Total class 1	56				
2s/v	161	None	Coarse texture	Soils have moderately coarse textures; vary in depth; have good permeability and adequate water-holding capacity for their class; and are susceptible to wind erosion. No major saline or sodic problems.	Lands are good source of planting media. Manage revegetated areas normally.
2s/p	22	None	Slow permeability	Soils have somewhat restricted permeability and moderate susceptibility to erosion. Saline and sodic problems not a major factor.	Lands are good source of planting media. Manage revegetated areas normally. Slow permeability will cause more than normal runoff; protect potentially affected areas.
Miscellaneous Class 2 3/	10	Salinity	Slow and very slow permeability	Soils are somewhat saline. Permeability and water-holding capacity somewhat restricted. Surface runoff anticipated.	Lands are fair source of planting media. If chosen for revegetation, careful management required.
Total Class 2	193				
3s/v	268	None	Coarse textures	Soils are coarse textured. In some cases, soils have very rapid permeability. Water-holding capacity generally poor. Soils very susceptible to wind erosion. No saline or sodic conditions in surface soils, but can occur in subsoils.	Lands are fair to good source of planting media. Because of coarse textures, more than normal protection from erosion required.
3s/s	63	Salinity	Slow permeability	Soils have saline problems and must be used with caution. Permeability is usually slow, and in some areas there is no moisture penetration. Water-holding capacity varies, but generally fair.	As a source of planting media, lands range from fair to poor. Take special care to prevent contamination of better soils. Mixing is recommended if better quality soils are available. Slow permeability or some surface sealing will cause more than normal runoff; protect potentially affected areas. If chosen for revegetation, very careful management required.
3s/a	31	Sodicity	Very slow permeability	Soils are sodic and usually seal over. In most cases permeability is very slow, sometimes it is zero. Soils susceptible to erosion.	Soils are rated fair to poor for use as a planting media. Take special care to prevent contamination of better soils. Mixing is recommended if better quality soils are available. Some of the poorer soils may need burying below root zone. Slow permeability or sealing will cause more than normal runoff; protect potentially affected areas. If chosen for revegetation, very careful management required.
3s/p	56	Usually saline-sodic affected	Very slow permeability	Soils have very slow permeability. Susceptibility to erosion is high. Soils are usually saline-sodic, especially in the subsoil.	Most of the soils would be poor planting media. Take special care to prevent contamination of better soils. Mixing is recommended if better quality soils are available. Some of the poorer soils may need burying below the root zone. Slow permeability or surface sealing will cause more than normal runoff; protect potentially affected areas. If chosen for revegetation, very careful management required.
Miscellaneous Class 3 3/	18	Saline-sodic affected	Coarse textures, very slow permeability	Soils are usually saline-sodic. Soils usually slowly permeable except, generally, where coarse textures occur. Some coarse-textured soils tend to be very slowly permeable. Soils are susceptible to erosion.	Most of the soils would be poor planting media. Take special care to prevent contamination of better soils. Mixing is recommended if better quality soils are available. Some of the poorer quality soils may need burying below the root zone. More than normal erosion protection required. Slow permeability or surface sealing will cause more than normal runoff; protect potentially affected areas. If chosen for revegetation, very careful management required.
Total Class 3	436				
6s/v	196	Very slightly saline-sodic affected	Coarse and very coarse textures with some gravel and cobble	Soils have coarse textures and sometimes contain gravel and cobble. Permeability is very rapid; available water-holding capacity is very poor. Soils susceptible to severe wind erosion.	These soils are not recommended as planting media. If soil is critically needed for mixing, however, these soils may be mixed with better quality soils taking extreme care in stripping, stockpiling, mixing, and placing. Place unsuitable soils well below root zone. Because of coarse textures, erosion protection is critical. If chosen for revegetation, very careful management required.
6s/sa	654	Saline-sodic affected	Very restricted permeability or impermeable	Soils are saline-sodic affected. Most areas have no moisture penetration and have poor water-holding capacity. Rapid runoff occurs. Soils susceptible to erosion.	Soils are not recommended for use, but careful mixing of these soils with better material may be acceptable if their use as planting media is absolutely required. Selection, handling, and placement must be very carefully done to assure success in use of these soils. Take special care to prevent contamination of better soils. Place unsuitable materials well below root zone. Limited permeability or surface sealing will cause more than normal runoff. Very careful management required.
6s/sa-p	104	Saline-sodic affected	Very restricted permeability or impermeable	Soils are usually less than 12" deep over bedrock, and are saline-sodic affected. Most areas have no moisture penetration, and rapid runoff occurs. Soils are susceptible to erosion.	Although not recommended, careful mixing of these shallow soils with better material may be acceptable if their use is absolutely necessary. Selection, handling, and placement must be very carefully done to assure reasonable success in use of this material. Take special care to prevent contamination of better soils. Place unsuitable material well below root zone. Limited permeability or surface sealing will cause more than normal runoff; protect potentially affected areas. If chosen for revegetation, the very careful management required will be difficult.
6s/-ap	436	Saline-sodic affected geologic material	Impermeable	This is primarily saline-sodic affected, impermeable geologic material. Rapid runoff occurs.	Although not recommended, careful mixing of these materials with high quality soils may be acceptable if material for mixing is critically needed. Place unsuitable material well below root zone. Impermeability will cause rapid runoff; protect potentially affected areas. Management will be extremely difficult.
6st/-apg	245	Saline-sodic affected geologic material	Impermeable; usually steep slopes; some severely eroded areas.	This area consists of severely eroded geologic formations. Steep slopes, outcrops, and crevices are the main topographic features. Material is saline-sodic affected. Rapid runoff occurs and material is susceptible to severe erosion. Topography will hinder stripping and stockpiling.	Although not recommended, where topography permits, mixing of these materials with high quality soils may be acceptable if material for mixing is critically needed. Place unsuitable material well below root zone. Rapid runoff from this material will require protection of adjacent areas. Management will be extremely difficult.
Total Class 6	1,635				
Grand Total	2,320				

1/ Lands were classed for their suitability as a source of planting media as follows:

Class	Suitability
1	good
2	fair
3	poor
6	unsuitable in present condition.

This table applies to about the top 36 inches of overburden at the study site.

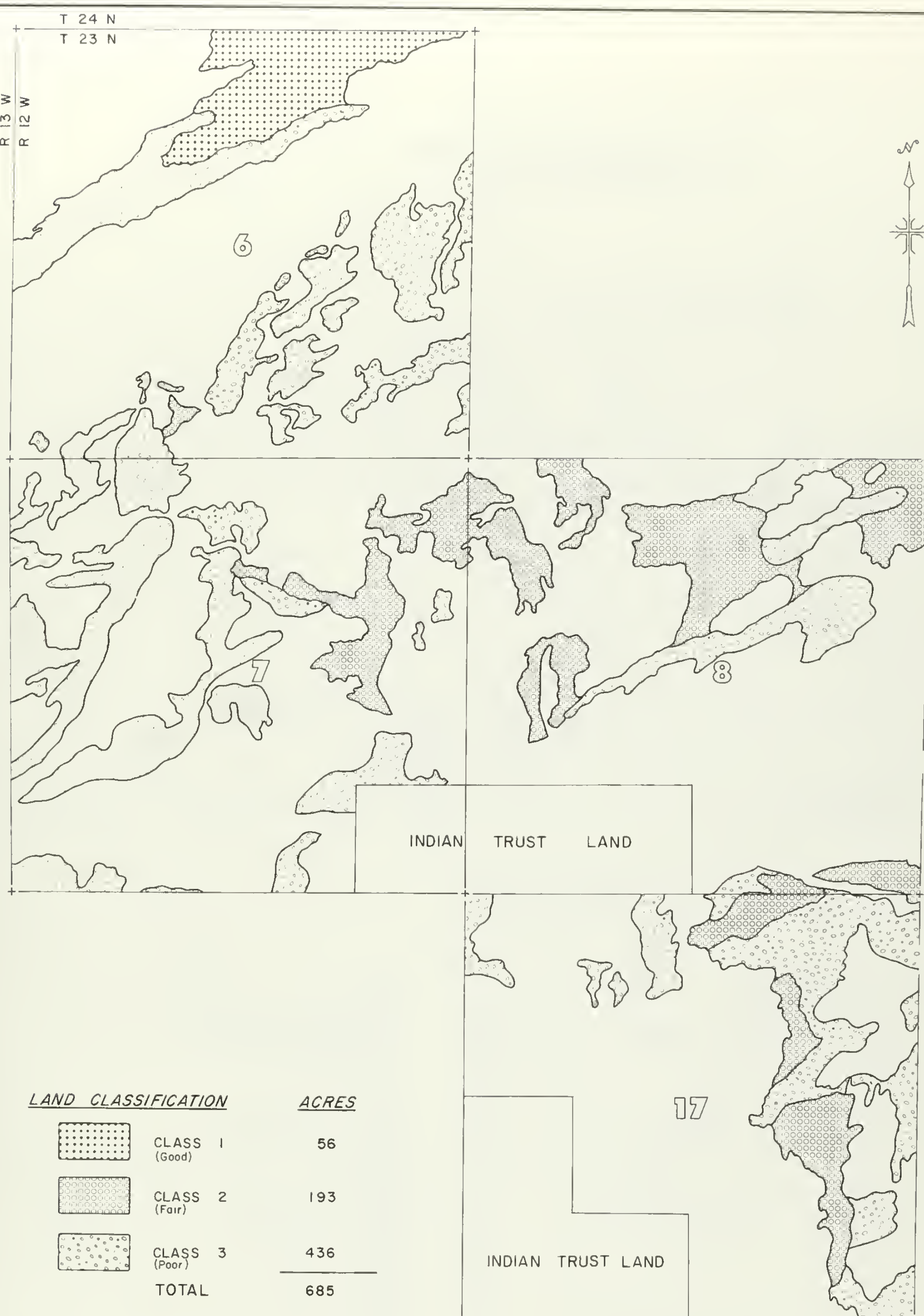
2/ 3s/v-p

- 3 — land class
- s — letter indicates subclass (major deficiency): due to soil (s) or topography (t)
- v — major subclass deficiency, above geologic material
- p — major deficiency of geologic material

This nomenclature is similar to that of figure 11.

v = very coarse
a = sodic
p = permeability
s = saline
g = excessive slope

3/ Classes with less than 10 acres.



LAND CLASSIFICATION	ACRES
CLASS 1 (Good)	56
CLASS 2 (Fair)	193
CLASS 3 (Poor)	436
TOTAL	685
CLASS 6 (Unsuitable)	1635
INDIAN TRUST LAND	240
GRAND TOTAL	2560

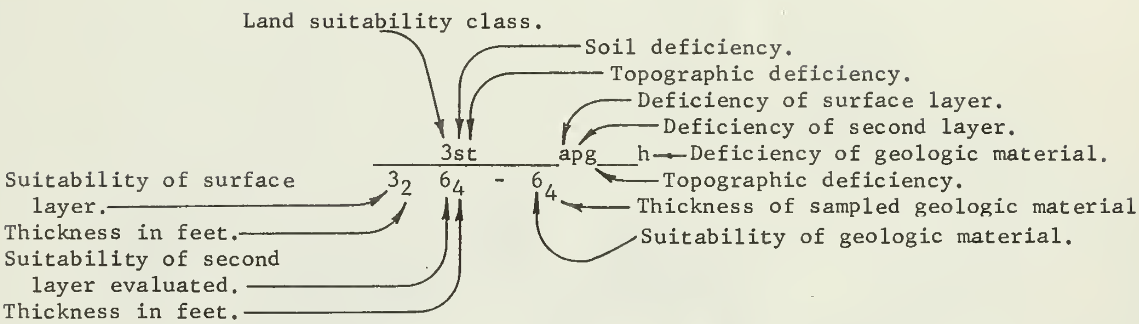
* LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

1000 0 1000 2000 3000 FEET

BISTI WEST STUDY SITE
COMPOSITE LAND CLASSIFICATION*
EMRIA REPORT NO. 5 -1976

FIGURE 9

Mapping and Profile Symbols for Land Classification

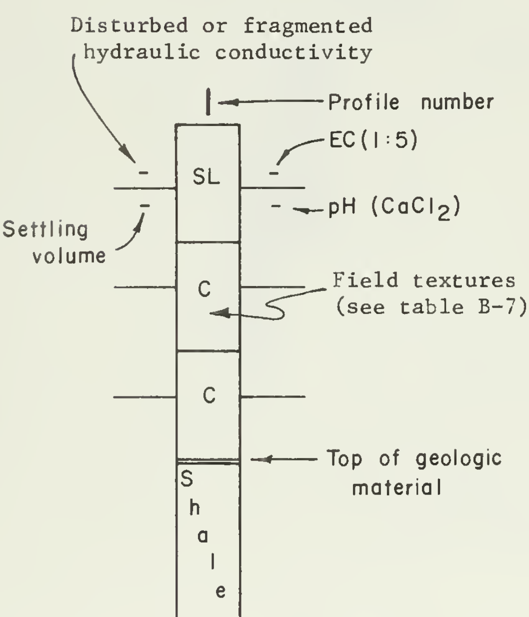


Land class suitability
- 1 good
- 2 fair
- 3 poor
- 6 unsuitable

Subclasses
- s - soils
- t - topography

Subclass deficiency
- v - very coarse texture
- a - sodic
- p - permeability
- s - saline
- k - shallow depth to coarse sand, gravel, or cobble
- g - slope

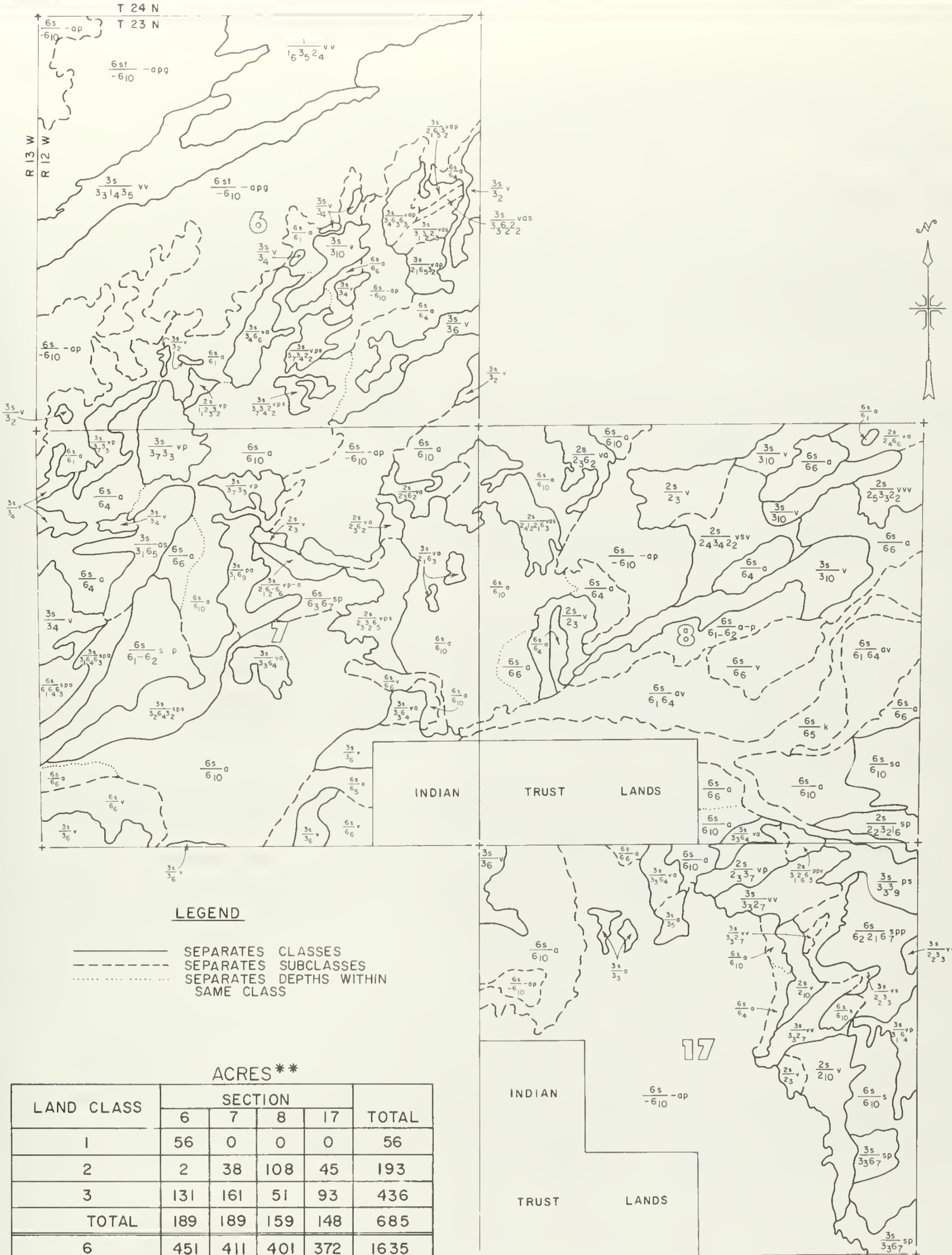
Profile Description



Textures

S	sand
fS	fine sand
VfS	very fine sand
LfS	loamy fine sand
LS	loamy sand
fSL	fine sandy loam
SL	sandy loam
L	loam
SiL	silty loam
CL	clay loam
SiCL	silty clay loam
SCL	sandy clay loam
SiC	silty clay
SC	sandy clay
C	clay
Sh	shale
SS	sandstone

FIGURE 10



LEGEND

SEPARATES CLASSES
SEPARATES SUBCLASSES
SEPARATES DEPTHS WITHIN SAME CLASS

ACRES**

LAND CLASS	SECTION 6	7	8	17	TOTAL
1	56	0	0	0	56
2	2	38	108	45	193
3	131	161	51	93	436
TOTAL	189	189	159	148	685
6	451	411	401	372	1635
INDIAN TRUST LAND	0	40	80	120	240
GRAND TOTAL	640	640	640	640	2560

** FOR COMPLETE ACREAGE OF EACH INDIVIDUAL LAND CLASSIFICATION SEE TABLE B-2

(This map duplicated in appendix at 1:12,000 scale for greater legibility)

* LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

1000 0 1000 2000 3000 FEET

BISTI WEST STUDY SITE

LAND CLASSIFICATION*

EMRIA REPORT NO. 5 -1976

FIGURE 11

A complete tabulation of land class and subclass acreages is presented in table B-2.

Bedrock suitability

Bedrock materials at the Bisti West study site are in two geologic formations--the Fruitland and Kirtland. The materials in these formations are discussed in the previous section on geology (especially the Study Site Geology subsection).

The results of selected physical and chemical properties tests performed on overburden and materials separating coal beds are summarized in table D-1. The materials were obtained as core samples from drill holes DH-1 through -7, located as shown on figure 7.

The weakly cemented overburden, as well as coal seam separations, consists of about 60 percent clayey materials, 25 percent sandy materials, and 15 percent silty materials.

Weathering tests indicate rapid breakdown of the materials. Of the total of 21 samples subjected to freeze-thaw tests, 20 showed 100 percent breakdown after 9 to 35 cycles, for an average of 17 cycles. Of the total of 21 samples subjected to 43 cycles of wet-dry testing, 7 showed 4.5 percent of 36.5 percent breakdown; the remaining samples showed less than 1 percent breakdown.

Rock in both the Kirtland Shale and Fruitland Formation disintegrates rapidly when subjected to freezing and thawing and to a lesser extent when subjected to wetting and drying. Broken rock on the surface of smoothed spoil piles is expected to disintegrate in 2 to 3 years. A few concretions and minor thin resistant sandstones will be more resistant to weathering but would constitute less than 1 percent of the materials in the spoil piles.

If not top-soiled and properly managed, smoothed spoil piles may develop a surface crust and be relatively impermeable to infiltration from precipitation. Laboratory results from the disturbed hydraulic conductivity tests indicate very limited moisture penetration in any of the core samples (table D-1). Wind erosion and blowing dust from unvegetated smoothed spoil piles could be somewhat more severe than that occurring under existing natural conditions.

Leaching of chemical constituents from the surfaces of smoothed spoil piles by runoff could be somewhat higher than that occurring under existing natural conditions.

The swell factor of excavated rock from the Kirtland Shale and Fruitland Formation is unknown but is expected to be relatively high because of the presence of appreciable amounts of montmorillonite in the shales, as indicated by the cation exchange capacity (CEC) (table D-1). CEC for 45 samples ranged from 3.9 to 108, averaging 68.9. This high average CEC confirms the high level (60 percent) of clayey materials cited above. This level of clay reduces the permeability of bedrock. Hydraulic conductivity (inches per hour) was 0.0 for all samples. The hydraulic conductivity determinations are not a measure of in-place permeability but reflect structure stability of remolded samples in the laboratory.

The total of 45 chemical analyses of saturated soil paste extracts (table D-1) indicate consistently high concentrations of sodium in most of the overburden and materials separating coal beds. Sodium concentrations ranged from 7.4 milliequivalents per liter (meq/l) to 112 meq/l, averaging 26.7 meq/l. Exchangeable sodium percentage (ESP) ranged from 0.5 to 59.7 percent, averaging 25 percent. Electrical conductivity (EC x 10^3 @ 25°C) ranged from 0.92 to 11.1 millimhos per centimeter (mmhos/cm), averaging 2.86. High levels of sodium such as these can adversely affect plant growth and soil permeability.

The above tests and others (see appendix B) and field investigations indicate that most bedrock materials are unsuitable as planting media. Revegetation of overburden spoil piles at the nearby Navajo coal mine indicates, however, that germination and young plant establishment on some bedrock material are possible under irrigation. Therefore, it may be possible at the Bisti West study site to mix some planting media with selected bedrock materials and achieve success (the high levels of sodium and clay in the bedrock thus could possibly be reduced). This must remain speculation until research identifies usable types of bedrock and determines the permanency of revegetation established by irrigation when irrigation is withdrawn.

The removing, transporting, and stockpiling of bedrock materials must be well managed to prevent contamination of planting media and water supplies.

Toxic materials

Selected tests and greenhouse studies (appendix B) of samples from the study site indicate no significant accumulations of toxic materials other than sodium. The more detailed soil survey to be conducted prior to mining, however, may reveal toxic materials or others unfavorable for plant growth. If this occurs, these materials must be properly identified and plans made to dispose of them so that planting media and water supplies are not contaminated.

Additional studies before mining

Before the soils of the study site are disturbed, the land classification conducted for this report should be refined to assure more accurate identification and proper disposition of all soils.

The field investigations, weathering tests, greenhouse studies, and laboratory analyses of study site bedrock were all performed on selected core (DH) materials. Data derived from these investigations, etc., represent only specific drill hole sites and should not be projected without additional investigations of the study site.

Because of the study site's severe climatic and soil conditions, its postmining reclamation will be very challenging, allowing only a moderate chance of success. To improve the chances of successful reclamation, considerable additional research must be conducted, including the use of onsite test plots and covering considerations such as soil treatment (as with gypsum), use of irrigation, erosion control, plant species, and management of revegetated areas.

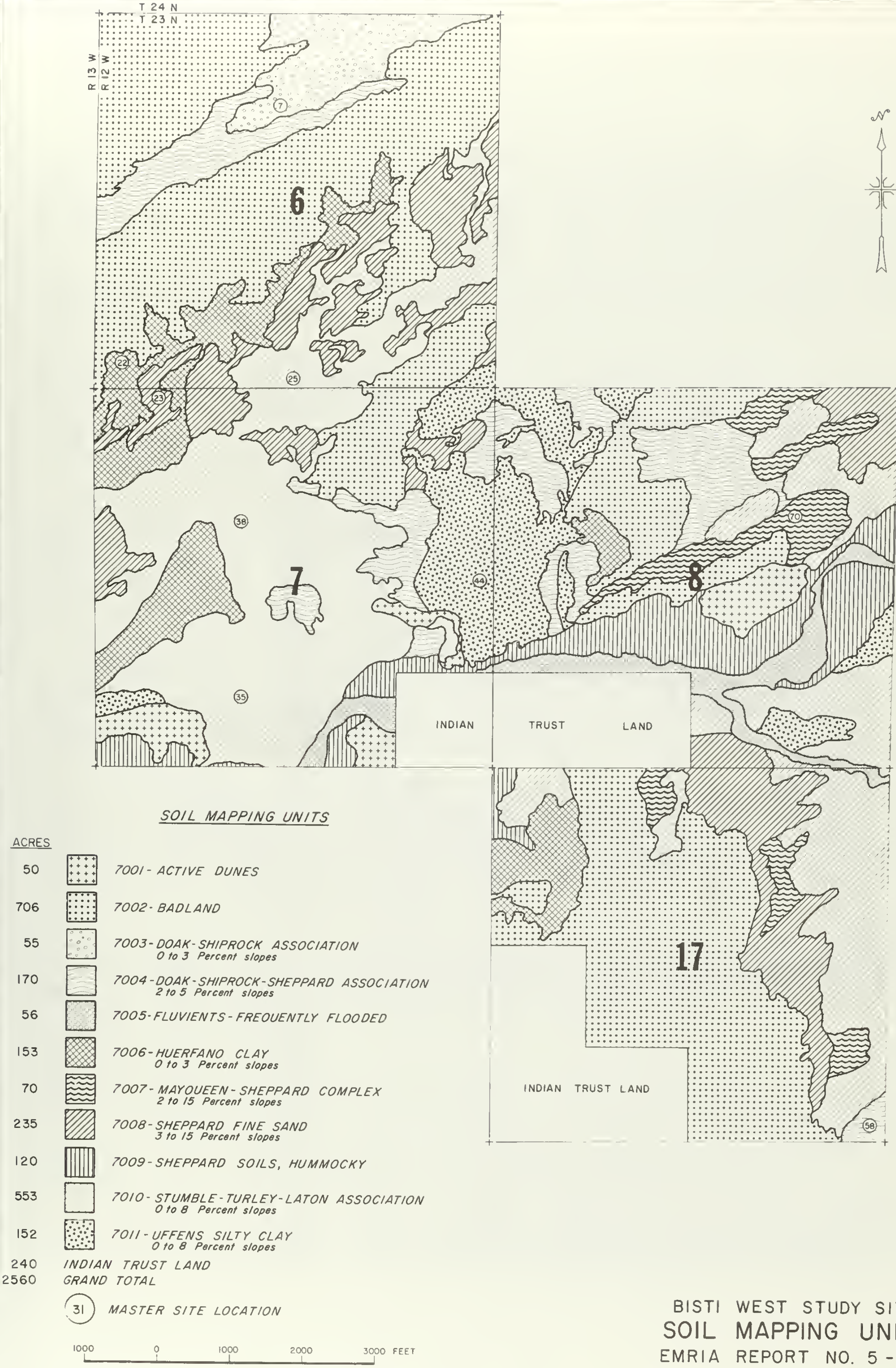
Some reclamation procedures will apply to the study site as a whole. Others must be unique to parts of it. Both types of procedures should cover stockpiling, protection of stockpiles, burying of unsuitable material, grading, drainage, and postmining use of the study site.

Soil inventory

A soil inventory was made to obtain basic soil and environmental data and to enable prediction of soil behavior and projection of soil information outside of the study site.

To facilitate the inventory, 11 soil mapping units (7001-7011) were delineated (figure 12) with assistance from the Soil Conservation Service (SCS) at Aztec, New Mexico. The units are not each equivalent to an individual soil series; rather, soils with similar or contrasting characteristics are grouped together to form a given unit. The major soil series composing the units are Doak, Huerfano, Laton, Mayqueen, Sheppard, Shiprock, Stumble, Turley, and Uffens. Table 8 gives the taxonomy of these series. Minor soil series (Grandview, Azfield, and Fruitland) and types, phases, and variations of the major series exist throughout the site. Because these minor series, etc., represent only a small percentage of the study site soils, they are treated as inclusions and are accounted for in the soil mapping unit descriptions. (Table B-1 gives averages for the mapping units.)

Included in some of the soil mapping unit descriptions are master site locations. These master sites represent a profile of the dominant soil series of a given mapping unit. The complete soil profile descriptions, locations, and other data for each of the master sites are given in



BISTI WEST STUDY SITE
SOIL MAPPING UNITS
EMRIA REPORT NO. 5 -1976

FIGURE 12

Table 8

Taxonomy of Soil Series at the Bisti West Study Site 1/

Series	Family	Subgroup	Order
Doak	Fine-loamy, mixed, mesic	Typic Haplargids	Aridisols
Huerfano 2/	Clayey, mixed, mesic, shallow	Typic Natrargids	Aridisols
Laton 2/	Fine, mixed, mesic	Typic Camborthids	Aridisols
Mayqueen	Coarse-loamy, mixed, mesic	Typic Haplargids	Aridisols
Sheppard	Mixed, mesic	Typic Torripsamments	Entisols
Shiprock	Coarse-loamy, mixed, mesic	Typic Haplargids	Aridisols
Stumble	Mixed, mesic	Typic Torripsamments	Entisols
Turley	Fine-loamy, mixed (calcareous), mesic	Typic Torriorthents	Entisols
Uffens 2/	Fine-loamy, mixed, mesic	Typic Natrargids	Aridisols

1/ For a discussion of taxonomic classification of soils, see appendix B.
Taxonomic hierarchy is: Order
Subgroup
Family
Series

2/ Not correlated, subject to change

tables B-8 to B-11. The Mayqueen series in mapping unit 7007 does not have laboratory data.

Active dunes (7001) (50 acres, 2 percent of study site). This land type consists of low hills and ridges of sand-sized particles drifted and piled up by the wind. No soil horizons have developed. Slopes vary over a large range, and local relief is 5 to 20 feet. These areas are usually elongated in the direction of the prevailing wind.

Inclusion of other soils make up less than 5 percent of the area. The dominant inclusion is Sheppard and represents the stabilized areas.

Permeability is very rapid and available water capacity is very low. Natural fertility level is very low and organic matter content is nearly zero. No surface runoff occurs. The erosion condition class is critical. Soil surface factors (SSF) are estimated over 81. There is little or no vegetative cover; wildlife use this land type.

Instability of this soil due to a very high wind erosion hazard and coarse texture limits the potential for all uses other than for wildlife. The soil is unsuitable as a plant growth media because of very low water-holding capacity and instability. There are no master site profiles in this mapping unit.

Badland (7002) (706 acres, 31 percent of study site). This land type consists of sloping to very steep barren land dissected by many intermittent drainage channels entrenched in soft shales and in sandstone. Numerous pedestals with sandstone caps are located here. Local relief is 0 to 100 feet.

Inclusions make up less than 15 percent of the association. They are usually Huerfano, Uffens, Turley, Stumble, Sheppard, the moderately coarse-textured shallow phase of Sheppard, the medium-textured phase of Turley, and a sandy loam phase of Stumble. All these soils are shallow, usually 6 to 12 inches deep.

Permeability is very slow, and available water capacity is very low. This land type is very low in natural fertility and organic matter content. Effective rooting depth is very shallow. The erosion condition class is critical. SSF is estimated to be over 81.

Native vegetation is nearly nonexistent with a few alkali sacaton, shadscale, and Russian-thistle in places. This land is used for range, wildlife, and recreation. This land type is unsuitable as a planting media because of the high sodic and saline condition of the geologic material. There are no master site profiles in this mapping unit.

Doak-Shiprock association, 0 to 8 percent slopes (7003) (55 acres, 2 percent of study site). This association consists of deep, well-drained soils that occur in a regular and repeating pattern of mesa

tops. The nearly level Doak soils occur on the lower mesa landscapes; the Shiprock on the higher landscapes.

Inclusions making up about 15 percent of the area are a medium-textured phase of Shiprock and the Grandview series that is similar to Laton.

Doak soils make up about 50 percent of the association. Typically, the surface layer is brown, loose, loamy fine sand about 6 inches thick. The upper subsoil is brownish-gray, hard clay loam about 22 inches thick. The lower subsoil is light reddish-brown, hard clay loam about 10 inches thick. The upper substratum is light reddish-brown sandy loam about 10 inches thick. The lower substratum is stratified, grayish-brown clay loam, pale brown loamy sand, and light yellowish-brown loam to a depth of 120 inches.

Permeability is moderately slow; available water capacity is high; effective rooting depth is more than 60 inches; surface runoff is slow; organic matter content is low; natural fertility is moderate. The erosion condition class is moderate. SSF is 47.

The native vegetation is galleta, blue grama, broom snakeweed, Indian ricegrass, sand dropseed, prickly pear, four-wing saltbush, and yucca. Lands of this association are used for range and wildlife.

Doak soils are potentially good planting media, notwithstanding low strength, moderate shrink-swell potential, and moderate erosion hazard.

Shiprock soils make up about 35 percent of the association. Typically, the surface layer is pale brown, loose loamy sand about 12 inches thick. The upper substratum is light yellowish-brown and pale brown sandy loam with calcium carbonate nodules about 24 inches thick. The middle substratum is light yellowish-brown loamy sand about 32 inches thick. The lower substratum is pale brown loose sand to a depth of 120 inches.

Permeability is moderately rapid. Available water capacity is moderate. Effective rooting depth is more than 60 inches. Organic matter content is low. Natural fertility is medium. Surface runoff is slow. The erosion condition class is moderate. SSF is 54.

The native vegetation is galleta, blue grama, Indian ricegrass, sand dropseed, ring muhly, Mormontea, four-wing saltbush, and big sagebrush. Lands of this association are used for range and wildlife.

Overall, Shiprock soils are potentially good planting media, but because of their moderately coarse texture and moderate available moisture capacity, they should be mixed with better soil.

Master site 7 (Shiprock series) in located in this unit, 2,700 feet east and 1,225 feet south of the NW corner, sec. 6, T. 23 N., R. 12 W.

Doak-Shiprock-Sheppard association, 2 to 15 percent slopes (7004) (170 acres, 7 percent of study site). This mapping unit consists of well to excessively drained soils that occur in a regular and repeating pattern. Lands of this unit occupy wind oriented sand dunes associated with broad depressions on mesa tops and sandy ridges. The nearly level Doak soils occupy the lower depressions, the gently sloping Shiprock soils occupy the intermediate slopes, and the rolling Sheppard and Mayqueen soils occupy the dune land.

Inclusions make up less than 10 percent of the association. These are a coal substratum of Doak and a barrier phase (6 feet) of Sheppard.

Doak soils, which make up about 40 percent of the association, are described above in mapping unit 7003. Shiprock soils, which make up about 20 percent of the association, are also described above in mapping unit 7003.

Sheppard and Mayqueen soils make up about 30 percent of the association. Typically, in Sheppard soils the surface layer is light yellowish-brown loose fine sand about 12 inches thick. The upper substratum is light yellowish-brown loose and slightly compact fine sand about 72 inches thick. The middle substratum is pale brown slightly compact loamy fine sand about 24 inches thick. The lower substratum is grayish-brown hard sandy clay to a depth of 120 inches.

Typically, in Mayqueen soils the surface layer is brown loose loamy fine sand about 3 inches thick. The subsoil is brown fine sandy loam about 9 inches thick. The subsoil is light yellowish-brown stratified loamy fine sand and fine sand to a depth of 60 inches.

Permeability is very rapid. Available water capacity is low. Effective rooting depth is more than 60 inches. Organic matter content is low. Natural fertility is very low. No surface runoff occurs. The erosion condition class is moderate for Mayqueen and Sheppard. SSF is 57 and 47, respectively.

The native vegetation is Indian ricegrass, needleandthread, ring muhly, spiny muhly, sand dropseed, Russian-thistle, sand sagebrush, Mormontea, and broom snakeweed. These soils are used for range and wildlife.

These soils are potentially fair planting media because of coarse texture, low available water capacity, and high erosion hazard. Saline and sodic conditions exist in some areas.

Master site 58 (Doak series) is located in this unit, 350 feet north and 250 feet west of the SE corner, sec. 17, T. 23 N., R. 12 W.

Fluvents-frequently flooded (7005) (56 acres, 2 percent of study site). These soils consist of many closely related soils that cannot be

separated into individual series. Their taxonomic classification is at the suborder; their textural family is estimated below. These soils occur in the stream channels and are frequently flooded.

Typically, these Fluvents have a wide range of texture and have variable profiles. Sand and gravel are dominant and would be considered to be of sandy or sandy skeletal families. Color ranges are variable and insignificant.

Permeability is rapid. These soils are flooded whenever local storms produce enough moisture for runoff. Erosion condition class is severe. SSF is estimated to be over 81.

Native vegetation is nearly nonexistant due to soil movement and to the abrasive action of sediment in the runoff water. Vegetation consists of saltcedar, greasewood, alkali sacaton, and shadscale on islands and along the channel margins.

These Fluvents are potentially poor planting media because of coarse sandy textures and instability.

There are no master sites in this unit.

Huerfano clay, 0 to 3 percent slopes (7006) (153 acres, 7 percent of study site). This mapping unit consists of shallow, poorly drained soils, generally sodium affected but in some areas saline. The soils formed in fine-textured alluvium and weathered shale and siltstone on mesas, valley bottoms, and valley side slopes.

Inclusions make up less than 15 percent of the association. These are Quake (similar to Huerfano); rock outcrops; Sheppard; Laton; a medium-textured, shallow phase of Sheppard; drifting sand in long narrow streaks below sandstone outcrops; and a coal substratum phase of Doak. Sheppard soils are deep and coarse textured; Laton is deep and fine textured.

Typically, Huerfano has a surface layer of grayish-brown clay about 3 inches thick. The subsoil is yellowish-brown clay about 9 inches thick. The substratum is weathered shale for about 24 inches; below this depth, the shale gets harder.

Permeability is very slow. Available water capacity is very low. Effective rooting depth is about 12 inches. Organic matter content is very low. The natural fertility level is very low. Surface runoff is very rapid. The erosion condition class is severe. SSF is 86.

The native vegetation is alkali sacaton, greasewood, fourwing saltbush, shadscale, saltbush, and Russian-thistle. This soil is used for range and wildlife. Almost all this soil is unsuitable as a planting media because of fine texture and high sodium content.

Master site 22 (Huerfano series) is located in this unit, 400 feet east and 400 feet north of the SW corner, sec. 6, T. 23 N., R 12 W.

Mayqueen-Sheppard complex, 2 to 15 percent slopes (7007) (70 acres, 8 percent of study site). This complex consists of Mayqueen soils intermingled with Sheppard soils and occupies stabilized dune land topography on or near mesa tops.

Inclusions in this mapping unit make up to 10 percent of this association. They consist of Fruitland, Farb (both similar to Turley), Shiprock, and various sandy soils with bedrock at less than 40 inches deep and a moderately coarse textured, shallow phase of Sheppard. Shiprock is deep and moderately coarse textured.

Mayqueen soils occupy 50 to 60 percent of the complex; they are described in mapping unit 7004. Sheppard soils occupy 35 to 45 percent of the complex; they are described above in mapping unit 7004.

These soils can be used as a planting media but are generally of poor quality because of coarse texture and poor water-holding capacity.

Master site 70 (Mayqueen series) is located in this unit, 1,550 feet west and 1,850 feet south of the NE corner, sec. 8, T. 23 N., R. 12 W.

Sheppard fine sand, 3 to 15 percent slopes (7008) (235 acres, 10 percent of study site). This soil consists of deep, somewhat excessively well drained and well drained soils formed in eolian sands in stabilized dunes on or near mesa tops and on high sandy valley areas. Some profiles had slow hydraulic conductivity, especially in the lower part.

Inclusions make up about 20 percent of the mapping unit. These are Doak; a moderately coarse textured phase of Sheppard; a hummocky phase of Sheppard; a sodic phase of Sheppard; a barrier phase (6 feet to bedrock) of Sheppard; a moderately coarse textured, shallow phase of Sheppard; and blowouts. Doak is moderately fine textured and deep.

Sheppard soils are described above in mapping unit 7004.

These soils can be used as planting media but because of this coarse texture and sodic condition, they should be carefully selected.

Master site 23 (Sheppard series) is located in this unit, 800 feet east and 125 feet south of the NW corner, sec. 7, T. 23 N., R. 12 W.

Sheppard soils, hummocky (7009) (120 acres, 5 percent of study site). These soils are deep, somewhat excessively drained. They formed in eolian sand on low terraces adjacent to De-Na-Zin Wash. Slope is 0 to 2 percent.

Inclusions make up about 20 percent of the area. These are stabilized dunes; rock outcrop (shale, sandstone, coal); and coarse-textured, shallow phases of Sheppard.

Some of these soils can be used as a planting media.

Sheppard soils are described above in mapping unit 7004. There are no master sites in this unit.

Stumble-Turley-Laton association, 0 to 8 percent slopes (7010) (553 acres, 24 percent of study site). This mapping unit consists of deep, generally poorly drained, coarse, moderately fine and fine textured alluvium. These soils occupy alluvial fans and flood plains.

Inclusions may make up to 20 percent of the association. These are the Blankot, Azfield, Fruitland, and Sheppard series; a sandy-loam phase of Stumble; a medium-textured phase of Turley; a fine loamy phase of Laton; and a sodic phase of Laton and Stumble.

Stumble soils make up about 30 percent of the association. Typically, the surface layer is light yellowish-brown loamy fine sand about 12 inches thick. The upper substratum is a light brown stratified loamy sand and a fine sand about 88 inches thick. The lower substratum is a dark brown and brown silty clay to a depth of 120 inches.

Permeability is very slow or zero because of high sodic conditions. Available-water capacity is low to very low. Effective rooting depth is generally 12 inches. Organic-matter content and natural-fertility level are very low. Surface runoff is very rapid and the erosion condition class is severe. SSF is 81.

The native vegetation consists of alkali sacaton, fourwing saltbush, shadscale, and Russian-thistle and is generally found only on coppice mounds or in depressions or filled rills. Vegetated areas represent less than 10 percent of the surface area. This soil is used for range and wildlife.

This soil is unsuitable as a planting media because of its high saline and sodic condition, very slow permeability, and an AWC of nearly zero.

Turley soils are somewhat poorly drained. They occupy about 25 percent of the association. Typically, the surface layer is pale brown clay about 12 inches thick; the upper substratum is stratified, light brownish-gray clay loam and pale brown silt loam about 36 inches thick. The lower substratum is pale brown fine sand to a depth of 120 inches.

Because of sodic soil conditions, permeability is very slow and effective rooting depth is about 12 inches. Available water capacity is very low. Organic-matter content and natural-fertility level are very low. Surface

runoff is very rapid. The erosion condition class is critical. SSF is 61.

The native vegetation consists of galleta, alkali sacaton, rubber rabbit-brush, and Russian-thistle and is generally found on coppice mounds or in depressions or filled rills. Vegetated areas represent less than 10 percent of the surface area. Lands of this soil type are used for range and wildlife. This soil has a poor potential for revegetation because of its high saline and sodic condition, slow permeability, and very low AWC.

Laton soils are poorly drained and occupy about 25 percent of the association. Typically, the surface layer is brown clay loam about 12 inches thick; the subsoil is grayish-brown clay about 12 inches thick. The upper substratum is dark grayish-brown clay about 44 inches thick; the lower substratum is brown loamy fine sand to a depth of 120 inches.

Permeability is very slow because of high sodic conditions. Available water is very low. Organic-matter content and natural fertility are very low. Surface runoff is very rapid. The erosion condition class is critical. SSF is 64.

The native vegetation consists of alkali sacaton, four-wing saltbush, shadscale, and Russian-thistle and is generally found on coppice mounds or in depressions or filled rills. Vegetated areas represent less than 10 percent of the surface area. Lands of this soil type are used for range and wildlife. This soil is unsuitable as a planting media.

Three master sites are located in this unit: Master site 25 (Stumble series), 2,500 feet east and 75 feet north of the SW corner, sec. 6, T. 23 N., R. 12 W.; Master site 35 (Turley series), 1,925 feet east and 850 feet north of the SW corner, sec. 7, T. 23 N., R. 12 W.; Master site 38 (Laton series), 1,900 feet east and 1,800 feet south of the NW corner, sec. 7, T. 23 N., R. 12 W.

Uffens silty clay, 0 to 8 percent slopes (7011) (152 acres, 7 percent of study site). This mapping unit consists of deep, poorly drained soils that are sodium affected. The soils formed in fine and moderately fine textured alluvium from shale or sandstone in low terraces and fans.

Inclusions make up about 15 percent of the mapping unit. These are the Fruitland, Azfield, and Doak series; a sandy-loam phase and a sandy-loam, sodic phase of Stumble; and a medium-textured phase and a medium-textured, sodic phase of Turley.

Typically, the surface layer is pale brown silty clay about 12 inches thick. The subsoil is pale brown sodic clay loam about 34 inches thick. The upper substratum is a pale brown very fine sand about 28 inches thick. The middle substratum is light yellowish-brown loose sand about

22 inches thick. The lower substratum is pale brown stratified loamy sand and sand to a depth of 120 inches.

Permeability is very slow. Available water capacity is very low. Effective root depth is about 12 inches. Organic-matter content and natural fertility are very low. Surface runoff is rapid. The erosion condition class is severe. SSF is 81.

The native vegetation is greasewood, shadscale, alkali sacaton, galleta, and four-wing saltbush. Lands of this soil type are used for range and wildlife. This soil is unsuitable as a planting media because of high sodic conditions.

Master site 44 (Uffens series) is located in this unit, 300 feet west and 2,400 feet north of the SE corner, sec. 7, T. 23 N., R. 12 W.

Vegetation

In general, the vegetation as shown on figure 13 is classified as northern desert shrub characterized by large amounts of bare soil and low vegetation yields. Some of the grasses, for example, galleta grass (*Hilaria jamesii*) and ring muhly (*Muhlenbergia torreyi*), are found only in the southern portion of the extensive northern desert shrub type. Habitats range from dune sand (site 7, table 9) with a cover of sand sagebrush (*Artemisia filifolia*) and torrey ephedra (*Ephedra torryana*) to salty lowlands (site 11) with greasewood as the dominant species. Deep (>60 inches) to shallow (<10 inches) sands occur on Alamo Mesa. Plants abundant on the stable (nondune) sands include four-wing saltbush (*Atriplex canescens*), Indian ricegrass (*Oryzopsis hymenoides*), and snakeweed (*Gutierrezia sarothrae*). Extensive areas below the mesa have alternating sandy and nonsandy soils. Alkali sacaton (*Sporobolus airoides*) is dominant on the sands and saltbush (*Atriplex obovata*) on adjacent nonsandy ground. Outcrops of scoria (porcellanite) near Tanner Lake have a sparse stand of galleta and alkali sacaton. A unique type (site 6) of limited extent but characterized by exposed weathered coal, has an almost pure stand of a shrub tentatively identified as *Eriogonum corymbosum*. Badlands (sites 8 and 9), with more than 90 percent of the soil surface without plant cover, occupy the transition between the mesa and the lowlands. None of the sites, with the possible exception of alkali sacaton on sandy lowlands (figure 13) would be considered productive. An estimated minimum of 51 sections of the present vegetation (nearly 32,760 acres) would be required to support a 300 animal-unit ranch. Weighted average carrying capacity is about 9.1 acres per animal-unit month. It was assumed that this area could be grazed yearlong (12 months). To obtain acres required for any grazing period for any of the vegetation types shown in table 9, multiply number of months times the acres per animal-unit month for each type. Yield data presented are average oven dry weights from two 9.6-square-foot plots in each vegetation type. Species were rated according to palatabilities to cattle--for other

EXPLANATION

Four-wing saltbush-Indian ricegrass. This type occupies deep, stable sands on the mesas. Understory grasses, Indian ricegrass and galleta form most of the plant cover.

Snakeweed-four-wing saltbush. On shallow sands of the mesas, snakeweed is the dominant shrub.

Galleta-alkali sacaton. Mixed stands of these grasses are found on scoria in the southern end of the study area.

Alkali sacaton. The dominant on shallow sands, below and west of the mesas, is alkali sacaton.

Eriogonum. Of limited distribution, this type is found on weathered coal in the southeast part of the study area.

Saltbush. On shallow soils, interspersed with shallow sands below the mesas, perennial (*Atriplex obovata*) and annual (*Atriplex patula hastata*) are dominants.

Badlands. Steep slopes adjacent to the mesas are almost entirely lacking in plant cover.

Greasewood. Adjacent to De-na-zin Wash there are extensive stands of greasewood and scattered colonies of saltcedar (*Tamarix pentandra*). The main understory species is alkali sacaton.

Sand sagebrush-Torrey ephedra. This type is found on unstable dunes near the south edge of Alamo Mesa.

Tanner Lake.

Barren. The channel of De-na-zin Wash has no plant cover.

● Locations of vegetation and soil sampling sites.

VEGETATION MAP OF BISTI WEST STUDY AREA--NEW MEXICO, 1975

Base from U.S. Geological Survey
Tanner Lake and Alamo Mesa West
7½-minute quadrangles

FIGURE 13

Table 9
Percent cover of vegetation, mulch, bare soil and rock, plus yields of vegetation and mulch in pounds per acre. Yields are in parentheses.
Bisti West Study Site

	Vegetation types.......	Four-wing saltbush-Indian ricegrass		Snakeweed-Four-wing saltbush		Galleta-Alkali sacaton		Alkali sacaton-mustard		Eriogonum		Sand sagebrush-Torrey ephedra		Badlands		Saltbush		Alkali sacaton		Greasewood	
	Site numbers...........	1		2		3		4 and 5		6		7		8		9		10		11	
Genus species	Common name	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)
Shrubs																					
Artemisia filifolia	Sand sagebrush	----	-------	----	-------	----	-------	----	-------	----	-------	6.2	(107.5)	----	-------	----	-------	----	-------	----	-------
Atriplex canescens	Four-wing saltbush	11.0	-------	3.7	(9.5)	----	-------	----	-------	----	-------	7.4	-------	3.7	-------	----	-------	----	-------	----	-------
Atriplex obovata	Saltbush	----	-------	----	-------	0.3	(15.5)	----	(5.5)	----	-------	----	-------	----	-------	14.3	(50.0)	----	-------	1.0	(9.0)
Ephedra torreyana	Torrey ephedra	----	-------	----	-------	----	-------	----	-------	----	-------	10.0	(142.5)	----	-------	----	-------	----	-------	----	-------
Eriogonum corymbosum	Eriogonum	----	-------	----	-------	----	-------	----	-------	15.0	(709.5)	----	-------	----	-------	----	-------	----	-------	----	-------
Gutierrezia sarothrae	Snakeweed	1.3	-------	12.7	(450.5)	1.3	(12.0)	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------
Sarcobatus vermiculatus	Greasewood	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	14.3	(47.5)
Grasses																					
Bouteloua gracilis	Blue grama	1.3	(39.5)	3.3	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------
Bromus tectorum	Cheatgrass	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	(0.5)	----	-------	----	-------
Hilaria jamesii	Galleta	10.0	(36.0)	3.0	-------	5.0	(16.0)	----	-------	----	-------	----	-------	----	-------	----	-------	0.3	(82.0)	----	-------
Muhlenbergia torreyi	Ring muhly	----	-------	----	-------	----	-------	----	-------	----	-------	5.0	(158.0)	----	-------	----	-------	----	-------	----	-------
Oryzopsis hymenoides	Indian ricegrass	22.7	(327.5)	----	-------	----	(1.5)	----	-------	----	-------	1.0	(117.0)	----	-------	----	-------	4.4	(12.5)	----	-------
Sporobolus airoides	Alkali sacaton	----	-------	----	-------	4.7	(19.5)	16.8	(139.2)	----	-------	----	-------	----	-------	6.4	(0.5)	45.4	(346.5)	----	(99.5)
Sporobolus cryptandrus	Sand dropseed	----	-------	----	(16.5)	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	1.3	(1.0)	----	-------
Forbs																					
Ambrosia sp.	Ragweed	----	-------	----	-------	----	-------	----	-------	----	-------	1.3	(2.0)	----	-------	----	-------	----	(0.5)	----	-------
Amsinkia sp.	Fiddleneck	----	-------	----	-------	----	-------	----	-------	----	(108.0)	----	(0.5)	----	-------	----	-------	----	-------	----	-------
Atriplex patula hastata	Spearleaf saltbush	----	-------	----	-------	----	(2.0)	2.2	(40.2)	1.7	-------	----	-------	1.3	(124.5)	3.0	(192.5)	----	-------	----	-------
Chenopodium alba	Lambs quarters	0.3	-------	----	-------	----	-------	----	-------	----	-------	1.3	-------	----	-------	----	-------	----	-------	----	-------
Eriogonum sp.	Wild buckwheat	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	0.7	-------	----	-------	----	-------	----	-------
Lappula sp.	Stickseed	----	-------	0.6	(4.0)	----	-------	----	-------	----	-------	----	-------	----	-------	----	(2.5)	----	-------	----	(23.0)
Lygodesmia juncea	Skeletonweed	----	-------	----	-------	----	-------	----	-------	----	-------	----	(0.5)	----	-------	----	-------	----	-------	----	-------
Oenothera serrulata	Primrose	----	-------	----	-------	----	-------	----	-------	----	-------	0.3	-------	----	-------	----	-------	----	-------	----	-------
Plantago purshii	Wooly Indian wheat	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	(4.5)	----	(1.0)
Salsola kali	Russian thistle	0.7	-------	----	(1.5)	3.3	(15.0)	----	(1.5)	----	(0.5)	----	-------	----	-------	2.3	(21.0)	3.3	(33.5)	----	(0.5)
Sisymbrium sp.	Mustard	----	(3.5)	----	-------	----	-------	23.2	(173.2)	----	(2.0)	----	-------	----	-------	7.7	(2.0)	1.3	-------	0.3	-------
Sphaeralcea parvifolia	Globemallow	1.4	(28.0)	0.6	(15.0)	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------
Unidentified forbs		0.3	(0.5)	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	----	-------	1.0	(15.0)	----	(6.5)
Mulch		6.0	(68.5)	11.7	(43.5)	8.7	(90.5)	6.2	(123.2)	4.7	(365.0)	10.0	(246.5)	0.3	(164.5)	7.3	(200.0)	2.3	(63.5)	16.0	(275.0)
Bare soil		45.0	-------	63.7	-------	38.0	-------	40.1	-------	56.6	-------	57.4	-------	94.0	-------	58.3	-------	40.7	-------	68.4	-------
Rock		----	-------	0.7	-------	38.7	-------	11.5	-------	22.0	-------	----	-------	----	-------	0.7	-------	----	-------	----	-------
Total live cover (percent) or total vegetation yield (lb/acre)		49.0	(435.0)	23.9	(497.0)	14.6	(81.5)	42.2	(359.6)	16.7	(820.0)	32.5	(528.0)	5.7	(124.5)	33.7	(269.0)	57.0	(495.5)	15.6	(187.5)
Estimated carrying capacity in acres per animal-unit month.			4.4		20.8		26.3		6.7		6.4		3.9		18.0		14.5		3.4		11.8

ungulates the carrying capacities would differ from those shown in the table. These estimates are intended as "ball park" figures only.

If the habitat that now supports alkali sacaton stands (shallow sands) could be increased following mining, productivity of this area would be considerably improved. A mixture of alkali sacaton and four-wing saltbush are the most desirable for the reclaimed area for large herbivore production. Four-wing saltbush provides protein, phosphorus, and carotene during the nongrowing season when dormant grasses provide mainly carbohydrates to grazing animals. Other desirable forage species that could be grown on the reclaimed shallow sands include Indian ricegrass, galleta, and blue grama.

The abundance of species now on the study site, such as the exotic Russian-thistle, snakeweed, and the annual mustard, indicates deterioration of this range due to past livestock grazing. The rare and endangered (threatened) forb, milk vetch (Astragalus accumbens), is reported to occur on gray clay sites in northwestern New Mexico, but none was observed on the study site.

Moisture Relationships in Soils Associated With the Vegetation

Storage of water in soils of the Bisti West study site is probably greatest in late winter or early spring, and storage usually is depleted to minimum levels by early summer. Storage levels by the end of summer can show a net increase if soil water derived from rainfall exceeds growth requirements of native vegetation and amounts evaporated. With precipitation patterns in mind, soils associated with the different plant types described in table 9 were sampled shortly after the start of the summer rain period. As a result, moisture storage near the surface is typical of summer conditions, while moisture retained at depth is indicative of minimum levels of storage.

In each of the figures 14-24, which follow, all values within the figures between the normal wet and maximum dry lines represent the average depth of water, in decimeters (see table 10 for metric-English conversion factors), depleted after a normal recharge of the indicated horizons or zones. This normal recharge (0.28 dm in figure 14) occurs over the fall and winter from rain and snowmelt. The values do not include water from precipitation events during the "dry-down" phase of spring and summer. These values, therefore, only provide a relative index of average annual amounts of evapotranspiration. The values between normal wet and maximum wet lines and the matching values associated with void-moisture capacity (VMC) (.98 dm in figure 14) are depths of water that can be held in voids that exceed those that are filled at normal wet. These excess voids are filled temporarily except in soils where drainage is impeded, and in most soils they are only partially filled each year. An unusually wet season is required to fill all of the voids to the maximum wet level.

Table 10

CONVERSION FACTORS

Metric	Multiply by	English
g (grams)	2.205×10^{-3}	pounds
mm (millimeters)	.03937	inches
cm (centimeters)	.3937	inches
dm (decimeters)	3.937	inches
m (meters)	39.37	inches
cm^3, cc (cubic centimeters)	.06102	cubic inches
g/cm^3, g/cc (grams per cubic centimeter)	62.43	pounds per cubic foot
g/cm^2 (grams per square centimeter)	.01422	pounds per square inch
	9.678×10^{-4}	atmospheres
	9.806×10^{-4}	bars
log (grams per square centimeter)		pF
$kg/m^2/h$ (kilograms per square meter per hour)	1.845	pounds per square yard per hour
	.2049	pounds per square foot per hour
kg/hm^2 (kilograms per square hectometer)	.8924	pounds per acre

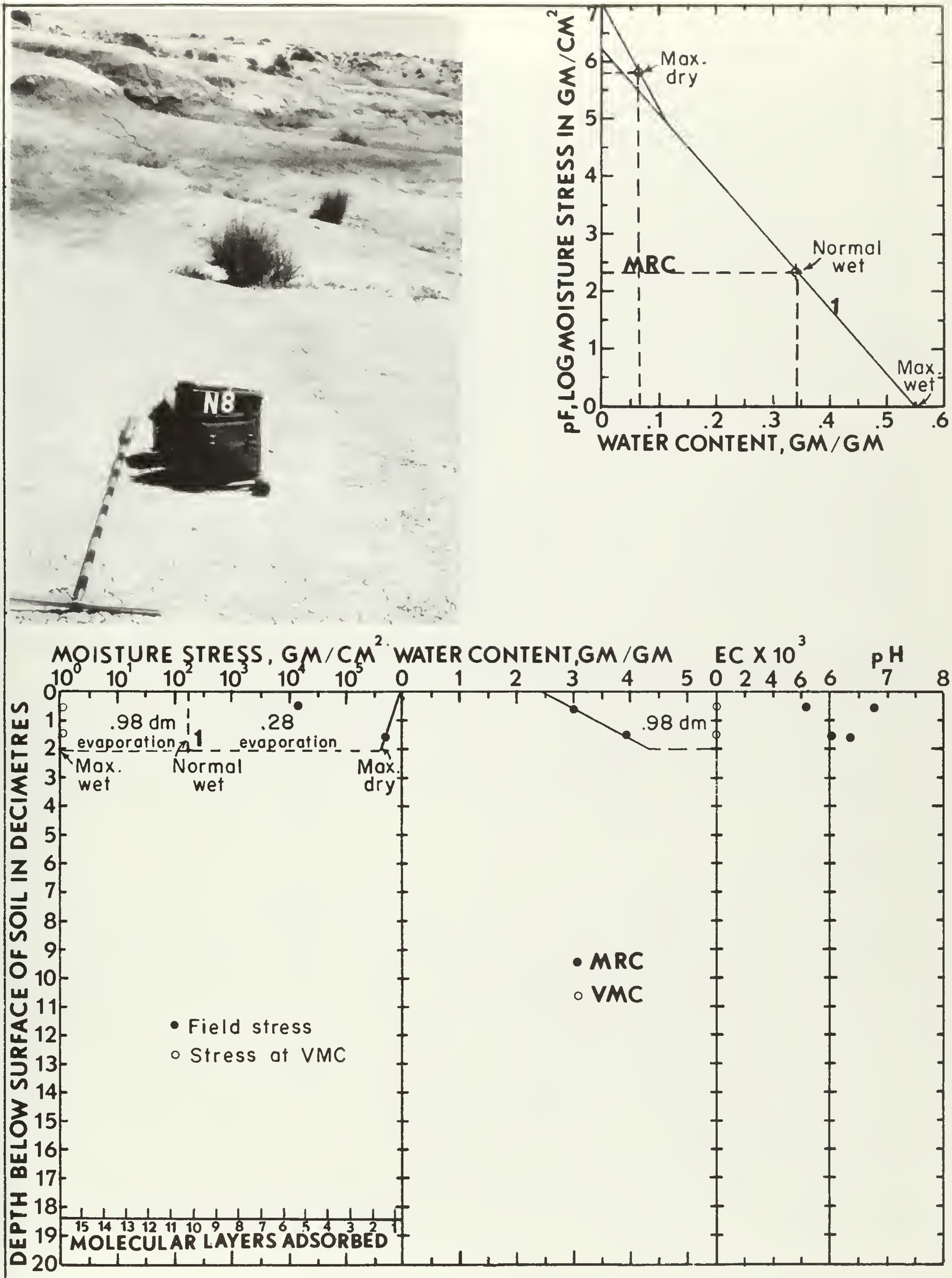


Figure 14 .--Soil-water properties of a nearly barren badland site (site 8, fig. 13).

Methods and concepts used to define moisture relationships are discussed in appendix C. It is recommended that this explanatory material be studied to better understand the discussion of moisture relationships in soils associated with vegetation types. (All of the base data from field sampling are presented in table C-1.)

There are three major categories of soil materials in the Bisti West area: (1) residuum from underlying shale and sandstone, (2) sandy alluvium of various depths, and (3) windblown sand. The productivity of soils developed in residuum is rather low, while infiltration and availability of water for plant growth is improved by the presence of sandy alluvium over residuum. Evaporation is reduced by the presence of windblown sand on the surface. The presence of excessive depths of sand can, however, result in less than optimum plant production.

Badlands type

The badlands type (site 8, figure 13, and table 9) occurs on steep slopes descending from Alamo Mesa where thin residual soils have developed in the exposed shale. Areas mapped as badlands (figure 13) have an extremely sparse cover of vegetation. Vegetation occurs only in depressions where sediment and runoff accumulate.

There is evidence (figure 14) that the thin mantle of soil is occasionally saturated. In fact, VMC exceeds saturation-moisture capacity (SMC) in the soil immediately above bedrock. Under these conditions, a maximum of 1.26 dm (.98 + .28 dm) of water could be lost from storage by evaporation. The water now being wasted through evaporation from badlands areas could be put to beneficial use if after surface mining the land surface is modified so that conditions are more favorable for vegetative growth.

Eriogonum type

The eriogonum type (site 6, figure 13, and table 9) occurs on soil with moisture-retention capabilities (MRC) similar to those measured in the badlands site. The area is flat, and the soil is deeper than required to retain all the water that infiltrates. This soil represents a phase of the Huerfano series. Data derived from this site (figure 15) provide evidence of low potential productivity if fine-textured soil is replaced on the surface following completion of mining activities. Here again, sparse xerophytic shrubs and forbs are the only vegetation. Because of the depth of soil present, drainage to MRC levels can occur. VMC exceeds MRC only in the upper 2 dm indicating that the soil is wetted to a level less than MRC at depths below 2 dm (figure 15). Void capacity in excess of MRC in the upper 2 dm is 0.42 dm of water. This is essentially the same as the 0.41 dm estimated to have been depleted from storage in the third horizon. The water in the third horizon was excess that could not be retained in the upper two horizons and, thus, moved downward after

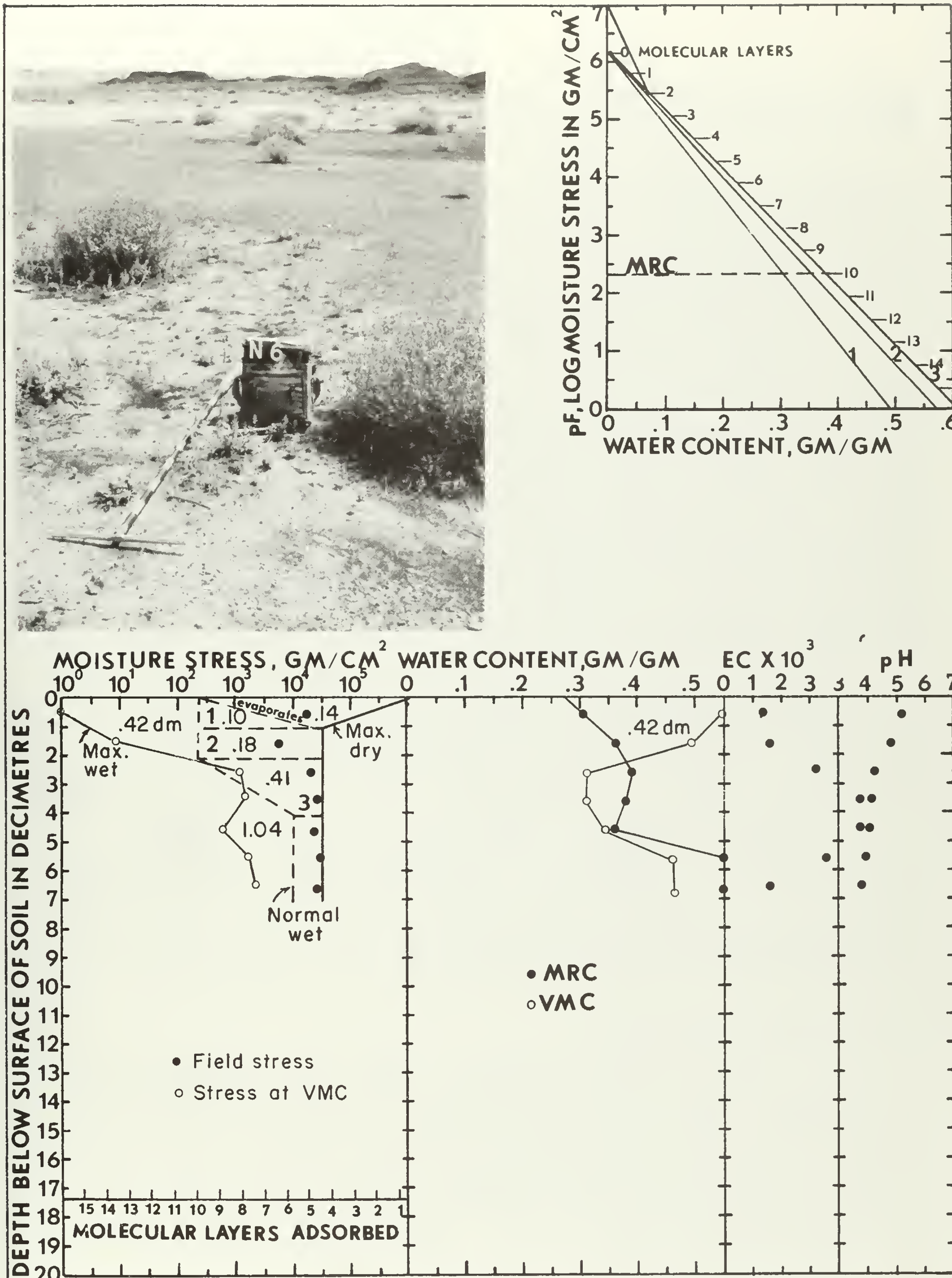


Figure 15 .--Soil-water properties of an alluvial site with Eriogonum cover (site 6, fig. 13).

initial entry into the soil. The 1.04 dm of water shown to the left of and below horizon 3 represents water stored between maximum dry moisture content and VMC during an unusually wet period.

Vegetation had depleted moisture storage from the MRC level, where 10 molecular layers of water are adsorbed to surfaces of soil particles, to the level where between four and five molecular layers of water remain. Moisture stress increases 2.46 times as each consecutive layer of water is desorbed, while 0.391 is added to the exponential or pF value. Thus, plants have to exert 2.46 times more force to desorb each consecutive layer of water. At the level where 10 molecular layers are adsorbed, the force is $10^{2.34}$ or 222 g/cm^2; at the ninth it is $10^{2.74}$ or 546 g/cm^2; at the eighth it is $10^{3.13}$ or 1,343 g/cm^2; at the seventh it is $10^{3.52}$ or 3,304 g/cm^2; at the sixth it is $10^{3.91}$ or 8,128 g/cm^2; at the fifth it is 19,999 g/cm^2; while removal of water to the surface of the fourth layer requires that a force of $10^{4.69}$ or 49,204 g/cm^2 be exceeded. The average maximum stress at depth in this soil was $10^{4.38}$ or 23,988 g/cm^2. This is in excess of the force of $10^{4.18}$ or 15,000 g/cm^2 (15 bars) defined as the wilting point for agronomic vegetation. Vegetation on the site was growing and healthy in July 1975, so it can be assumed that more water could be desorbed. With the advent of summer rains, moisture stored near the surface is available at lower levels of stress so further depletion at depth would not occur until moisture stored near the surface is depleted.

It is assumed that evaporation occurs to the level where only one molecular layer is adsorbed to particles at the ground surface, grading down to the level where between five and six molecular layers are adsorbed at a depth of 1 dm. The stress in the evaporation zone (figure 15), therefore, increases from $10^{4.38}$ or 23,988 g/cm^2 to $10^{5.86}$ or 732,844 g/cm^2, as the surface of soil is approached. Water that evaporated in excess of levels transpired had to be replenished before water from summer rain became available to vegetation. A proportionate amount of the rainwater stored at stresses less than the transpiration limit will also be evaporated. Thus, it is assumed that 0.14 dm of the 0.24 dm, or 58 percent, of the water evaporates from the surface decimeter after each precipitation event that fully recharges that layer.

Galleta-alkali sacaton type

The galleta-alkali sacaton type (site 3, figure 13, and table 9) occurs in areas where fine-textured residuum is covered by a mantle of baked rock fragments. This soil would probably be considered a phase of the Huerfano soil series. The presence of grasses indicates that moisture is more readily available than in the previous two sites. The greater wetness of this site is also indicated by evidence (figure 16) that voids appreciably exceed MRC at all depths. VMC in excess of the MRC levels 2.1 dm (.52 + 1.58) of water. Added to the 1.07 dm (.36 + .30 + .41) depleted between MRC levels and maximum depletion levels, a maximum

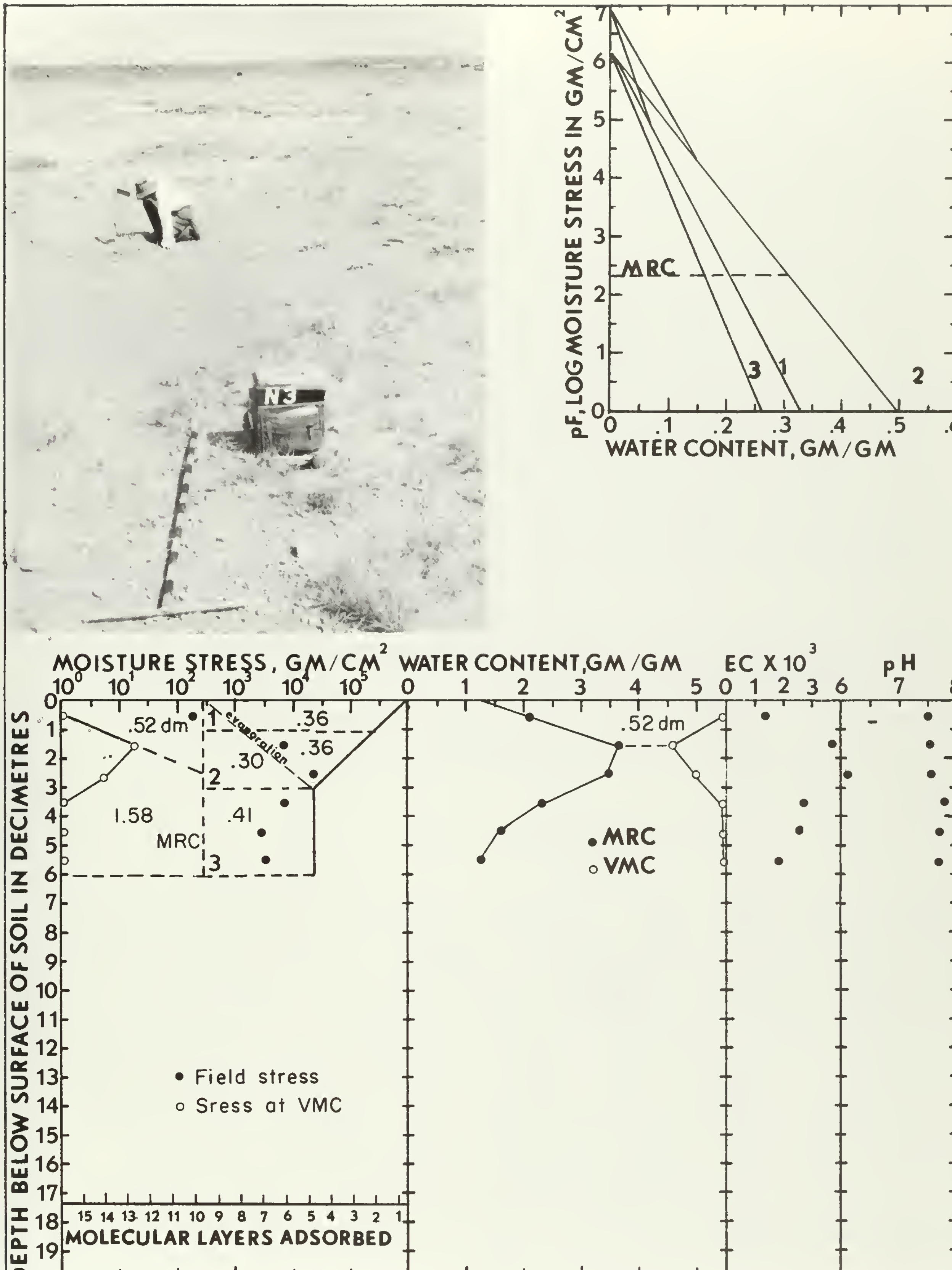


Figure 16.--Soil-water properties of a site in the Galleta-alkali sacaton typ where fine-textured residuum is mantled with baked rock fragments (site 3, fig. 13).

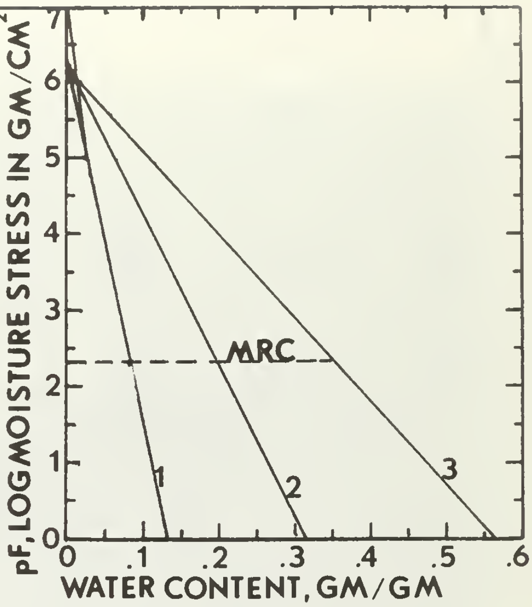
of 3.17 dm has at sometime (at least once) been stored in and depleted from this soil. Storage in excess of MRC levels is probably a normal occurrence. Infiltration is apparently facilitated by the mantle of rock fragments on the surface, while bedrock at a depth of 6 dm impedes drainage of water to greater depths. This water then accumulates, first in adsorbed films up to 16 molecular layers in thickness, then as capillary water, and then, perhaps, some free perched water accumulates.

If perched or ground water accumulates, the maximum stress at the ground surface would be equivalent to 1 gm for each centimeter of height above the water table. Sixteen molecular layers of water remain adsorbed to surfaces of soil particles after the ground water and capillary water around it are depleted. Energy requirements to desorb the top six molecular layers of water are quite minimal. The force increases 2.46 times for each molecular layer desorbed, increasing from 1 to 2.46 g/cm^2 as the sixteenth layer is desorbed, to 6.5, 14.9, 36.6, 90.2, and finally to 222 g/cm^2 as the surface of the tenth layer is encountered. Desorption of the ninth layer requires an even more appreciable increase in sorption force to 546 g/cm^2. The appreciable increase in stress in the vicinity of 10 molecular layers of water indicates why drainage tends to be appreciably slower, accounting for the phenomenon of field capacity.

The maximum stress at the time of sampling was approximately $10^{3.50}$ or 3,000 g/cm^2; this level of stress is evident near the base of the profile. Stresses greater than this level higher in the profile resulted from evaporation rather than transpiration. A minimum of 0.36 dm of water is lost to evaporation. Thus, it is apparent that the rocks on the surface facilitate evaporation as well as infiltration. The rocks absorb and hold heat from the sun, increasing evaporation from the medium-textured soil.

<u>Saltbush type and alkali sacaton-mustard type</u>

The saltbush type (site 9, figure 13, and table 9) and alkali sacaton-mustard type (sites 4 and 5, figure 13, and table 9) occur on lowlands where fine-textured residual soil, originally Huerfano series, is covered by a thin mantle of sandy alluvium. Evidence presented in figures 17, 18, and 19 indicates that even though the soils have similar MRC, different quantities of water are stored, primarily because duration of flooding varies. Flooding is no doubt infrequent, but it has left its imprint in the form of voids. VMC in excess of MRC increases with duration of flooding. Site 9 (figure 17), with a cover of both annual and perennial saltbush and alkali sacaton, can retain 0.91 dm of water in voids that exceed the MRC in volume. This somewhat exceeds the amount estimated as being stored below the 4 dm depth in the solum. With a cover of alkali sacaton and annual saltbush, site 4 (figure 18) can retain 1.04 dm of water in voids that exceed MRC levels. This appreciably exceeds the 0.36-dm capacity computed for the third horizon. This means that movement of water from the 1 and 2 horizons into the 3



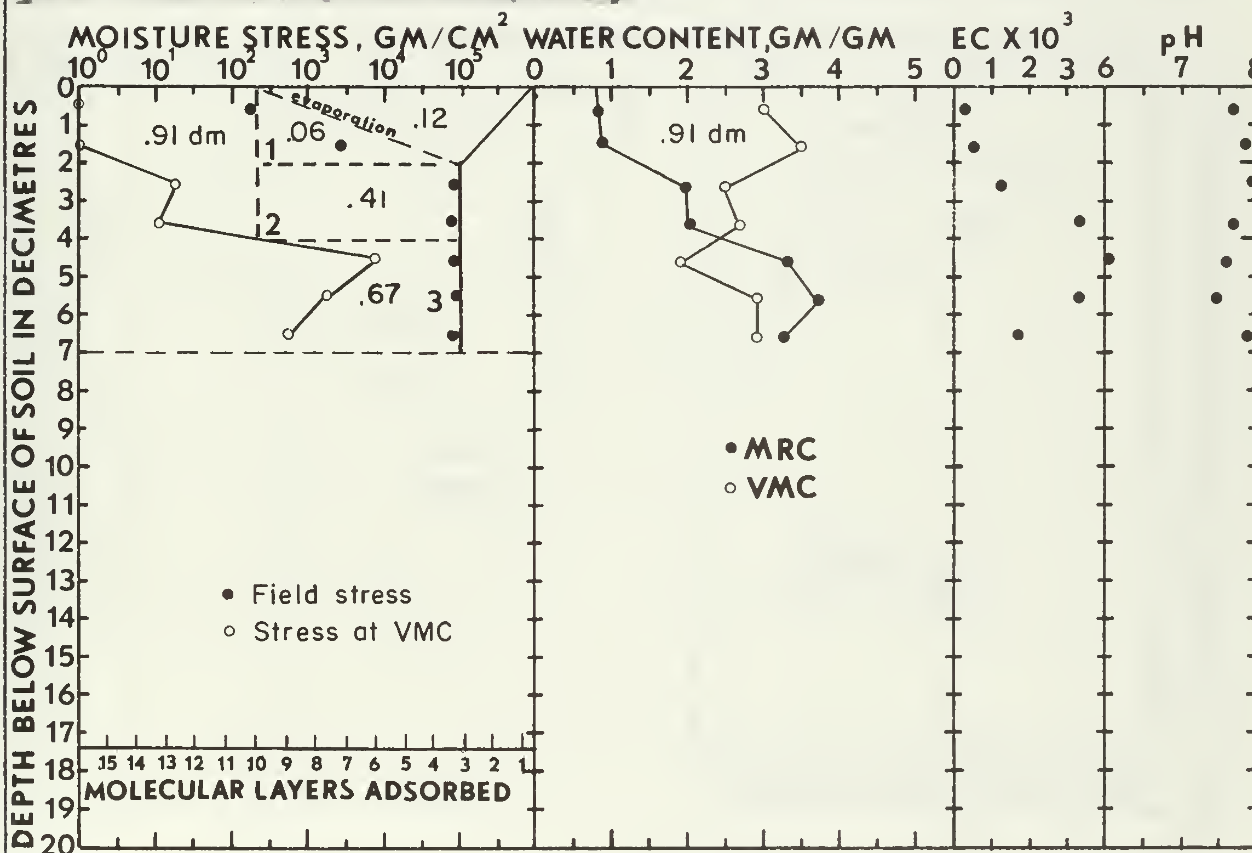


Figure 17 .--Soil-water properties of a saltbush and alkali sacaton site where fine-textured soil is mantled with sandy alluvium (site 9, fig. 13).

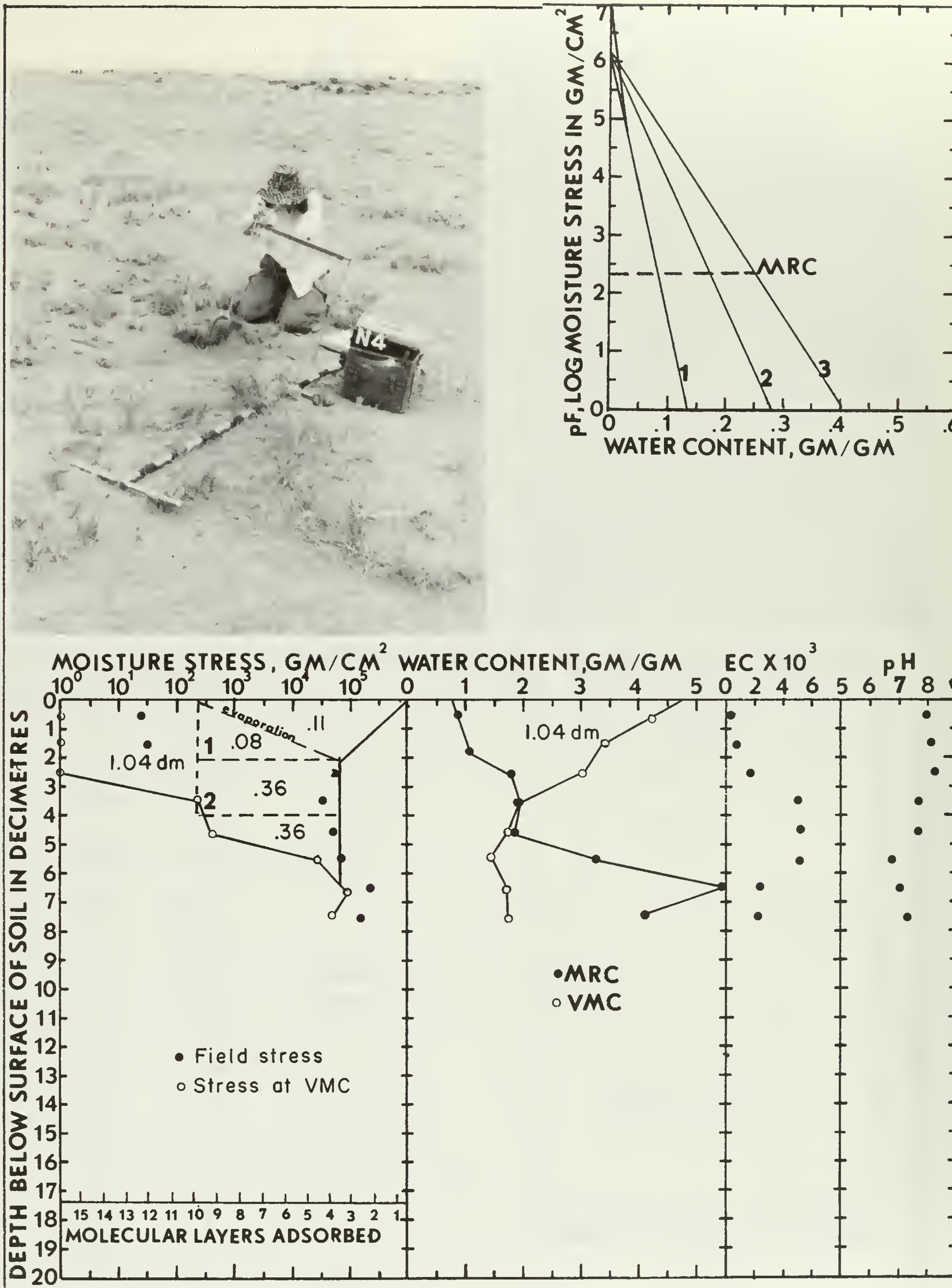


Figure 18.--Soil-water properties of an alkali sacaton-mustard site where a fine-textured soil is mantled with sandy alluvium (site 4, fig. 13).

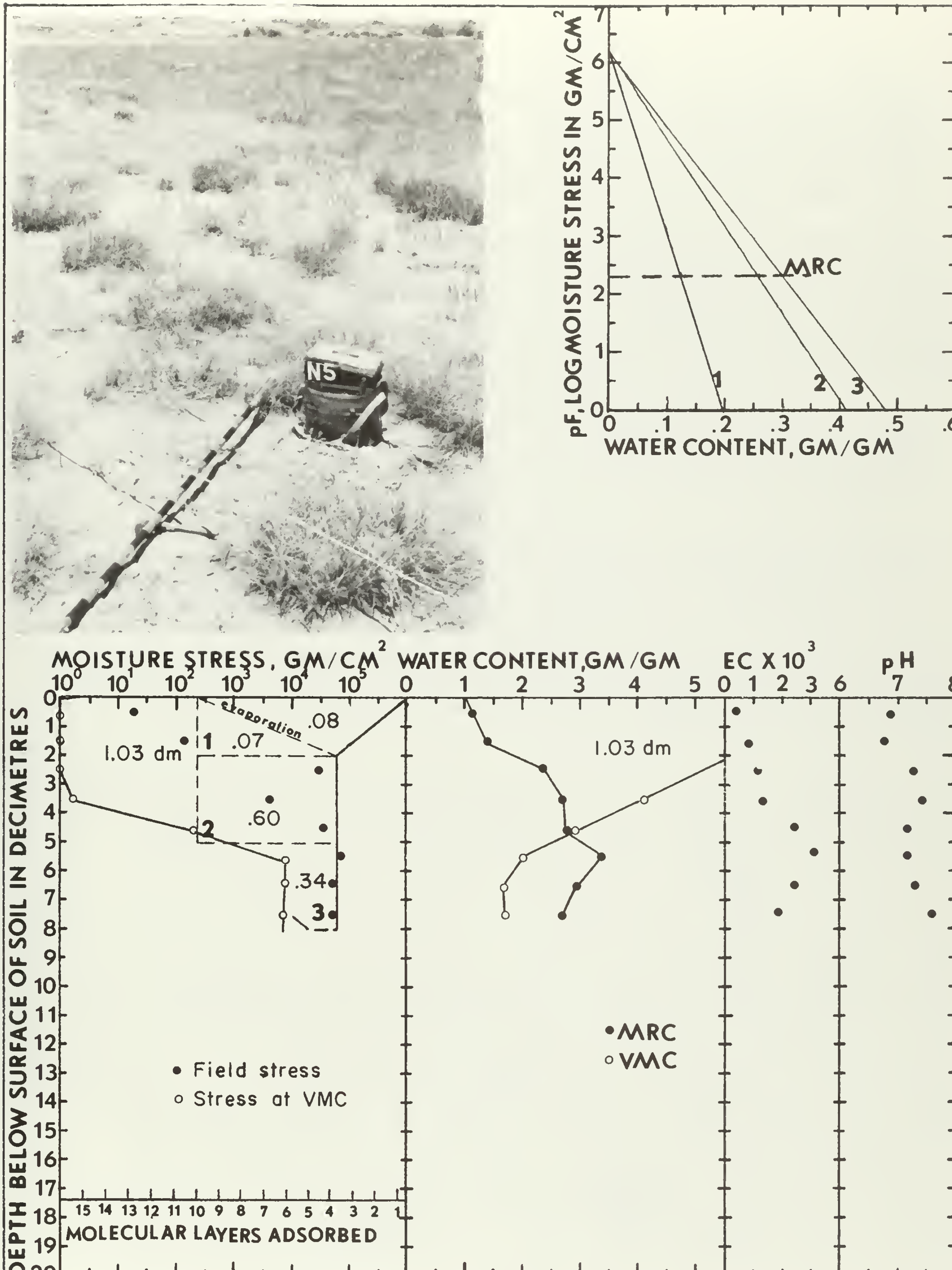


Figure 19.--Soil-water properties of an alkali sacaton-mustard site that is benefitted by run-in water (site 5, fig. 13).

horizon is impeded and causes additional water to be readily available from the upper horizons. Moisture storage in excess of 10 molecular layers apparently occurs frequently. Grass rather than saltbush predominates on this site, apparently because some water is available at stress levels less than $10^{2.34}$ or 222 g/cm^2.

Site 5 (figure 19) with a cover of mustard, alkali sacaton, and annual saltbush has a VMC that exceeds the MRC by 1.03 dm. This exceeds the amount of water depleted from the soil beneath by 0.69 dm (1.03 - .34). Moisture storage in excess of 10 molecular layers is, therefore, even greater in this soil than in the soil at site 9. This approaches the maximum number of layers that can be adsorbed beneath capillary water; so water is, on occasion, more readily available from this site than the other two sites. Comparisons of the water storage characteristic of sites 4, 5, and 9 indicate that differences in porosity and availability of water can be induced by factors that determine the frequency of flooding and the duration of wetting.

The level to which moisture was depleted from the solum by transpiration is indicated by maximum levels of stress evident at depth in the solum. Soil associated with the saltbush type depleted moisture approximately to the level where three molecular layers are adsorbed, while the two sites defined as the alkali sacaton-mustard type were depleted only to the level where four molecular layers of water remain. Grass and forbs predominate on the sites where the least energy is required to extract water, while saltbush predominates where maximum levels of energy are required to extract water.

Evaporation to a depth of 2 dm is estimated for all three sites. This is predicated on evidence of the stress gradients in figures 18 and 19 at depths below 2 dm. Average moisture depletion from the surface horizon of these three soils is approximately 0.19 dm. Approximately 0.11 dm, or 58 percent, is assumed to be lost to evaporation.

Four-wing saltbush-Indian ricegrass and snakeweed-four-wing saltbush types

The four-wing saltbush-Indian ricegrass and snakeweed-four-wing saltbush types (sites 1 and 2, figure 13, and table 9) occur on deep sandy loam soil that covers Alamo Mesa. The soils are both phases of the Mayqueen Series. These soils are grossly similar in MRC to the sandy alluvium deposited over residuum in the lowlands. Moisture penetrates to greater depths where the solum is completely comprised of sandy soil. Electrical conductivity (EC x 10^3, figures 20 and 21) data indicate leaching of salts to depth below about 9 dm in both soils. It is assumed that drainage to 10 molecular layers of water frequently occurs to these depths. The base of the second horizon (figures 20 and 21) was defined on the basis of this evidence. VMC is equivalent to or exceeds MRC levels at all depths in these soils, so there is no significant impedence to penetration of moisture beyond the profiles during wetter periods.

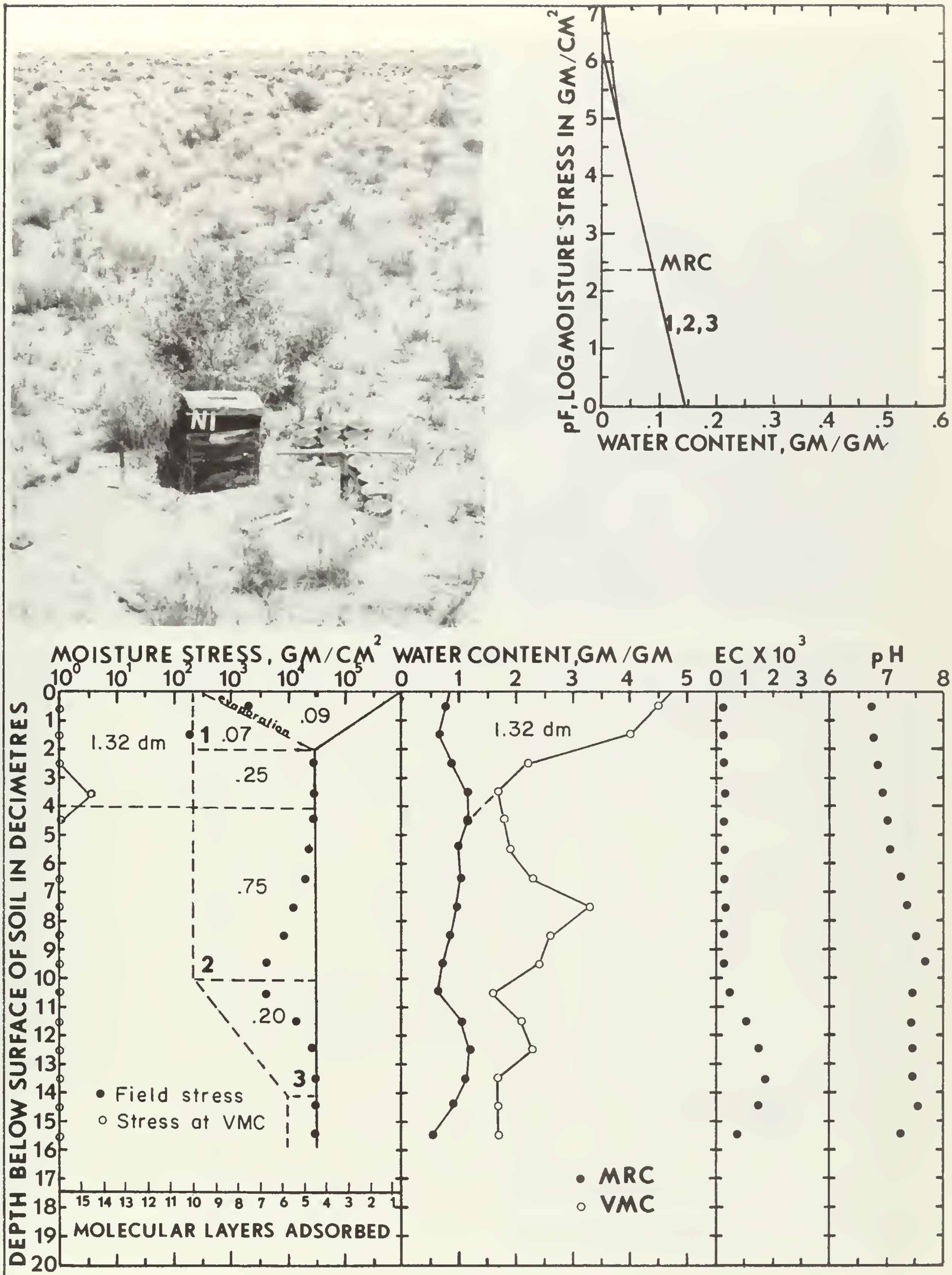


Figure 20.--Soil-water properties of a four-wing saltbush and Indian ricegrass site on deep sandy soil (site 1, fig. 13).

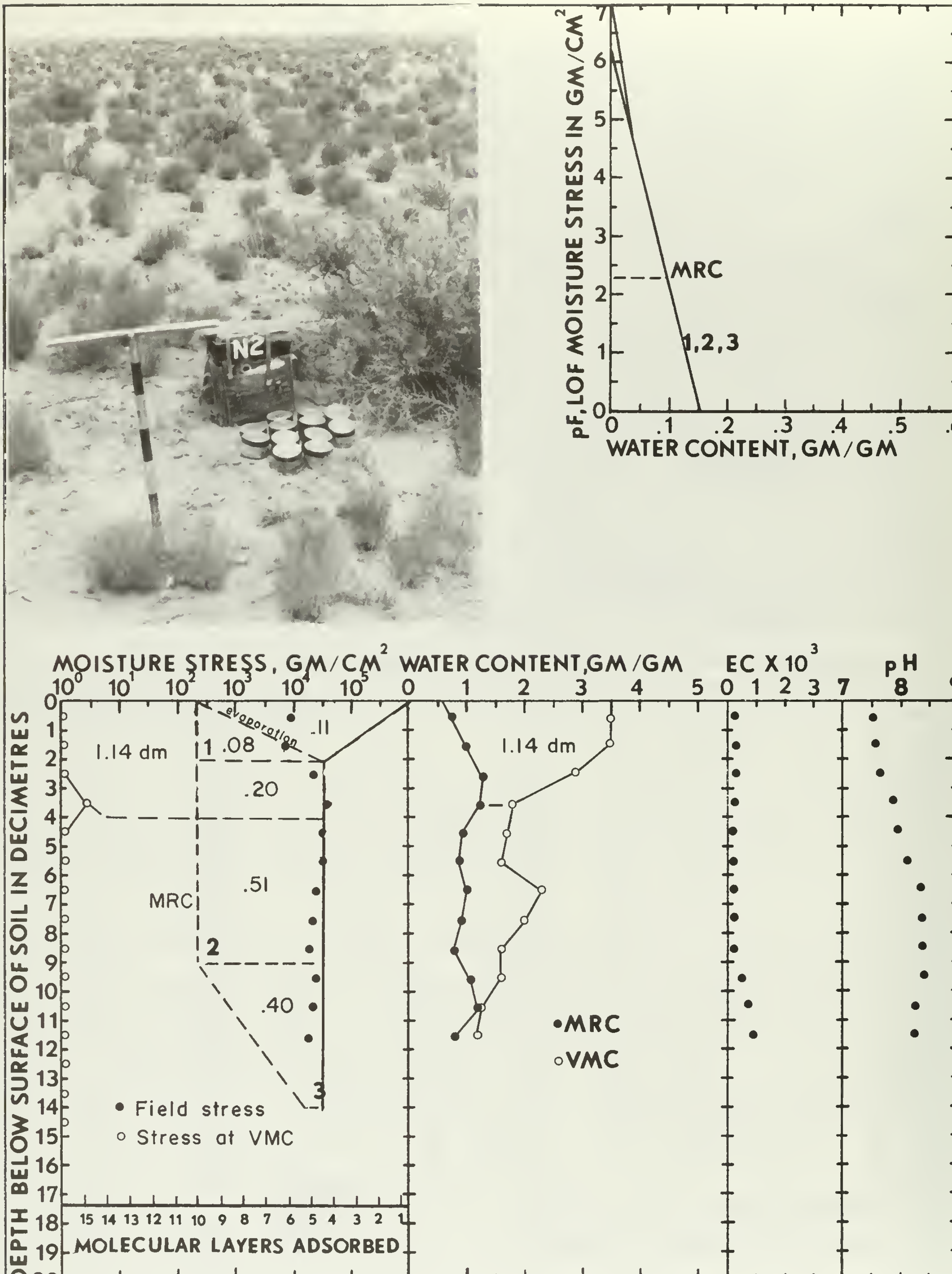


Figure 21 .--Soil-water properties of a snakeweed and four-wing saltbush site on deep sandy soil occurring in a swale (site 2, fig. 13).

Voids progressively decrease with depth in both soils and approach levels where only adsorbed water, 16 molecular layers or less thick, is held. Therefore, drainage to depth would have to occur as film flow.

Potential void-moisture storage in excess of MRC is 1.32 dm for the grassy site (figure 20) as compared to 1.14 dm for the shrubby site (figure 21). Added to quantities of water normally depleted below MRC levels, totals of 1.73 dm (1.32 + .09 + .07 + .25) and 1.53 dm, respectively, would be available from these soils. If all of the water was stored as films of 10 or less molecular layers thick, greater profile depths than those indicated in figures 20 and 21 would be required. These total values are probably maximums, while the plots of moisture stress versus depth in figures 20 and 21 represent the normals. The difference in cover between the two sites could be a result of more intensive grazing of the shrubby (figure 21) area because it occurs in a swale where there would be more shelter from winds.

Evaporation is assumed to occur to a depth of 2 dm in these soils because they have a sandy-loam texture. Evaporation loss from the grassy site (figure 20) is .09 dm, or 52 percent, of the moisture normally depleted from the surface horizon, while evaporation from the shrubby site (figure 21) is 0.11 dm, or 58 percent.

Sand sagebrush--Torrey ephedra type

The sand sagebrush--Torrey ephedra type (site 7, figure 13, and table 9) occurs on partially stabilized sand dunes at the edge of Alamo Mesa. There is evidence (figure 22) that moisture relationships in windblown dune sand differ from that in the sandy alluvium of sites 4, 5, and 9, which were discussed previously. The windblown sand consists of particles relatively uniform in size, while a range of particle sizes is present in the sandy alluvium. As a result, there is much less adsorptive surface in the dune sand than in the sandy alluvium. This difference is reflected by the extremely low MRC for dune sand. VMC greatly exceeds laboratory SMC near the surface of the dune and gradually decreases with depth in the upper 6 dm (figure 22). In the dunes at this site, and at other sites with a mantle of windblown sand, the large void capacities could be a function of loose packing resulting from deposition rather than separation of particles by water entering the soil. There is evidence of a similar zone of decreasing voids between 10 and 12 dm deep that could well be a relic of a previous depositional sequence. Voids become minimal at a depth of 11 dm. This is near the top of the zone where there is evidence of increased electrical conductivity (figure 22, EC x 10^3). Even in this zone of maximum compaction, voids exceed the adsorption moisture capacity or volume required to retain 16 molecular layers of adsorbed water. Thus, infiltration of water and migration to depth should not be impeded to any extent in dune sand.

There is evidence that water is stored at the MRC level ($10^{2.34}$ or 222 g/cm^2) at depths below 14 dm in the sand dune, indicating that moisture

penetrates to greater depths than were measured. The pattern of moisture storage and depletion is typical of what might be expected under humid conditions where water percolates down past the root zone and recharges ground water. This is due to the fact that dune sand is incapable of holding much water near the surface.

There is evidence that water derived from a rain 1 day prior to sampling was adsorbed in films 12 molecular layers thick (figure 22) rather than the 10 layers occurring at MRC levels. Drainage to depth by film flow is no doubt impeded as a result of minimal contacts between sand grains.

Evaporation losses from dune sand is less than from finer materials even though evaporation is assumed to occur to greater depths. The decrease in evaporation loss is due to the small amount of water retained on the surfaces of sand particles. Based on the assumptions made, .04 dm of the .10 dm of water, or approximately 40 percent of the water retained in the upper 3 dm is lost to evaporation. Because of the low MRC of dune sand, seedling establishment might be quite difficult without artificial irrigation.

Alkali sacaton type

The alkali sacaton type (site 10, figure 13, and table 9) occurs on lowland areas where deep sandy alluvium is covered by varying depths of windblown sand. This windblown sand apparently has not had as much fine sand removed by wind action as the dunes on the edge of Alamo Mesa (site 7) as MRC is somewhat greater at site 10 (figure 23). It is quite likely that this mantle of sands of assorted sizes has been blown in and deposited around grass already growing on the sandy alluvium. The presence of this windblown material results in high VMC that facilitates infiltration to depth. Actual establishment of alkali sacaton in the windblown material as a revegetation treatment would probably be difficult because of its low MRC.

Voids in the buried alluvium near its contact with the windblown sand at the 4-dm depth are only capable of retaining 16 molecular layers of adsorbed water. A maximum of 1.91 dm of water can accumulate in voids in excess of MRC within the mantle of windblown material. Drainage of this water to depth must occur as film flow and not capillary flow. Drainage to the MRC level where 10 molecular layers are adsorbed would not be impeded at any depth. A maximum of 2.33 dm is probably depleted from this soil. This would require moisture storage below depths to which this soil was sampled.

With drainage to MRC levels unimpeded, very little water is assumed to be available at stresses less than $10^{2.34}$ or 222 g/cm^2, while the average maximum stress evident at depth was $10^{4.22}$ or 66,069 g/cm^2. At this level of stress, the fourth molecular layer is being depleted. Since alkali sacaton did not appear to be stressed, it can be assumed

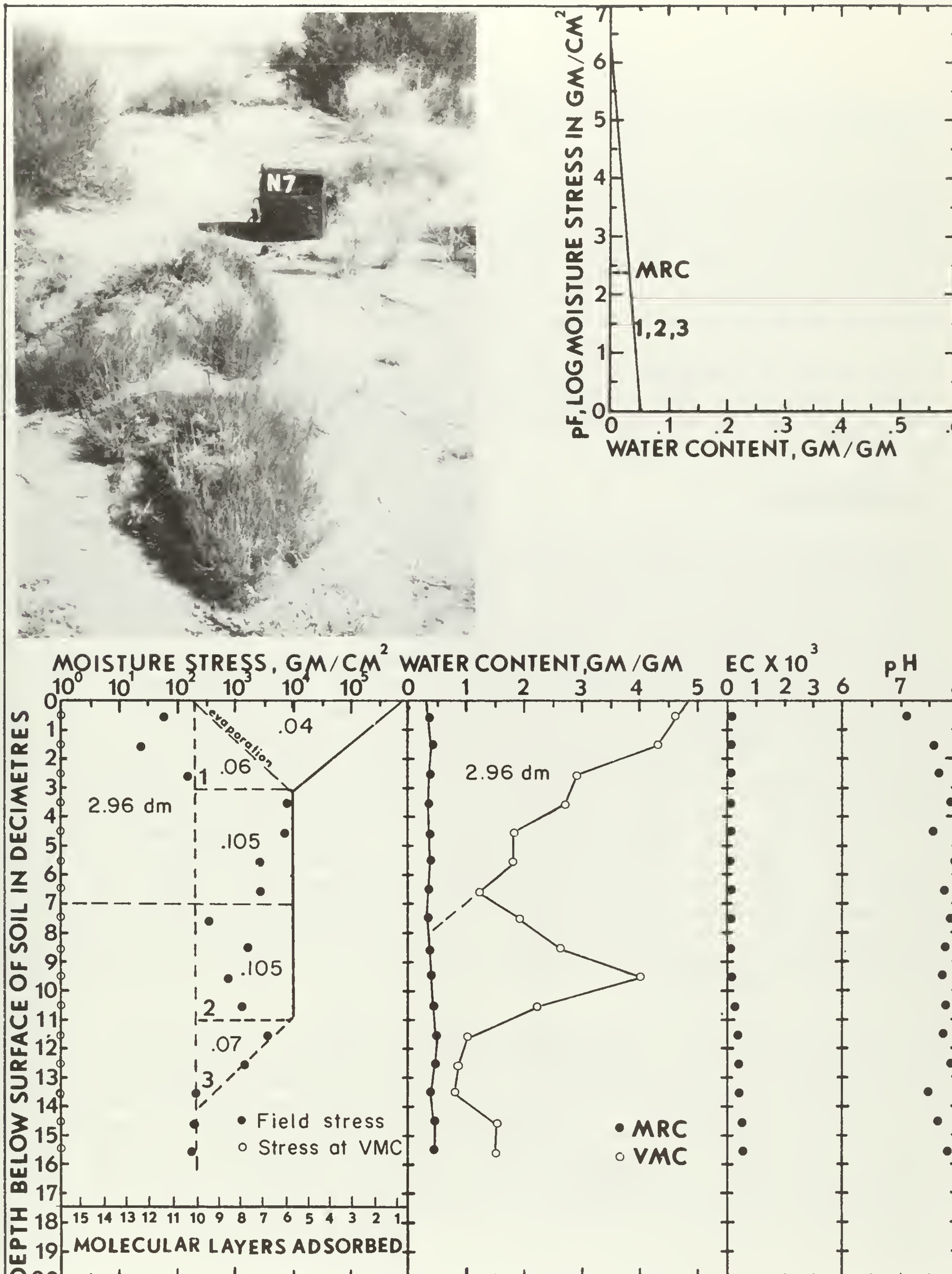


Figure 22.--Soil-water properties of a windblown sand deposit on the edge of Alamo Mesa (site 7, fig. 13). The vegetation is sand sagebrush, Torrey ephedra, ring muhly, and Indian ricegrass.

that this grass is capable of desorbing moisture to the level where three molecular layers are adsorbed.

Evaporation to a depth of 3 dm is indicated (figure 23). It is estimated that 0.13 dm of the 0.19 dm, or 68 percent of the water depleted from storage in the upper 3 dm is evaporated. Even with the high proportion of loss, the loss in comparison to total storage is lower than for most soils on the study site. These data, however, demonstrate why seedling establishment could be difficult because very little available moisture would be present in the upper 3 dm.

A thin mulch of windblown sand might help increase infiltration and reduce evaporation, but experimentation would be required to determine what thickness of this material would be optimum for enhancing seedling establishment.

Greasewood type

The greasewood type (site 11, figure 13, and table 9) occurs on sandy to loamy alluvium adjacent to De-Na-Zin Wash where ground water is within reach of plant roots. This soil was not wetted appreciably by a rain 1 day before sampling even though there is evidence (figure 24) that VMC appreciably exceeds MRC in the surface material. This could be the result of decomposition products from greasewood leaves inhibiting wetting of the soil. Water from snowmelt probably enters the soil because the duration of the wetting period is greater. VMC decreases to a level just sufficient for 16 molecular layers to be adsorbed at a depth of 4 dm. VMC becomes less than MRC at 8 dm where finer textured material appears and into which very little water penetrates from the ground surface. The upper 4 dm of soil is capable of holding a maximum of 1.96 dm in voids that exceed MRC. Only 0.46 dm evidently drains to depth. The remaining water could be stored as films greater than 10 molecular layers thick. It is surprising that under these conditions, the vegetative cover is not better. Poor infiltration from summer rains could account for the absence of grass. There is evidence that evaporation occurs to a depth of 4 dm with 0.25 dm of the 0.45 dm, or 44 percent, depleted by evaporation.

There is evidence that ground water is being utilized by greasewood because stresses become progressively lower below 10 dm. The actual water table was not contacted; but low levels of stress at a depth of 25 dm indicate that water left behind by a receding water table is present, probably as adsorbed films. The magnitude of this ground-water resource should be defined, because it could be utilized to temporarily irrigate areas where vegetation is being reestablished. Irrigation would help produce voids that would facilitate infiltration when the irrigation is withdrawn.

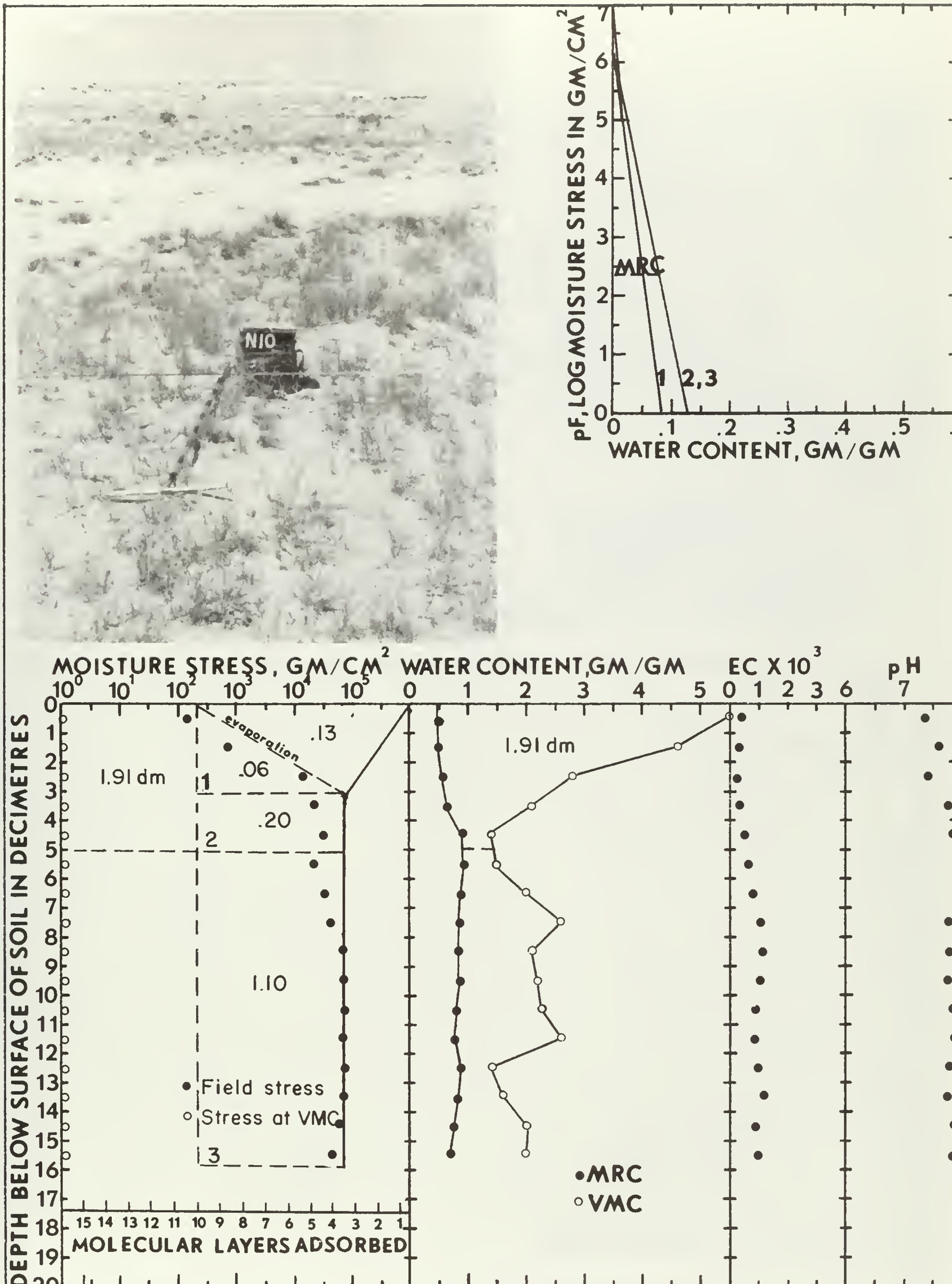


Figure 23.--Soil-water properties of an alkali sacaton site that has windblown sand overlying sandy alluvium (site 10, fig. 13).

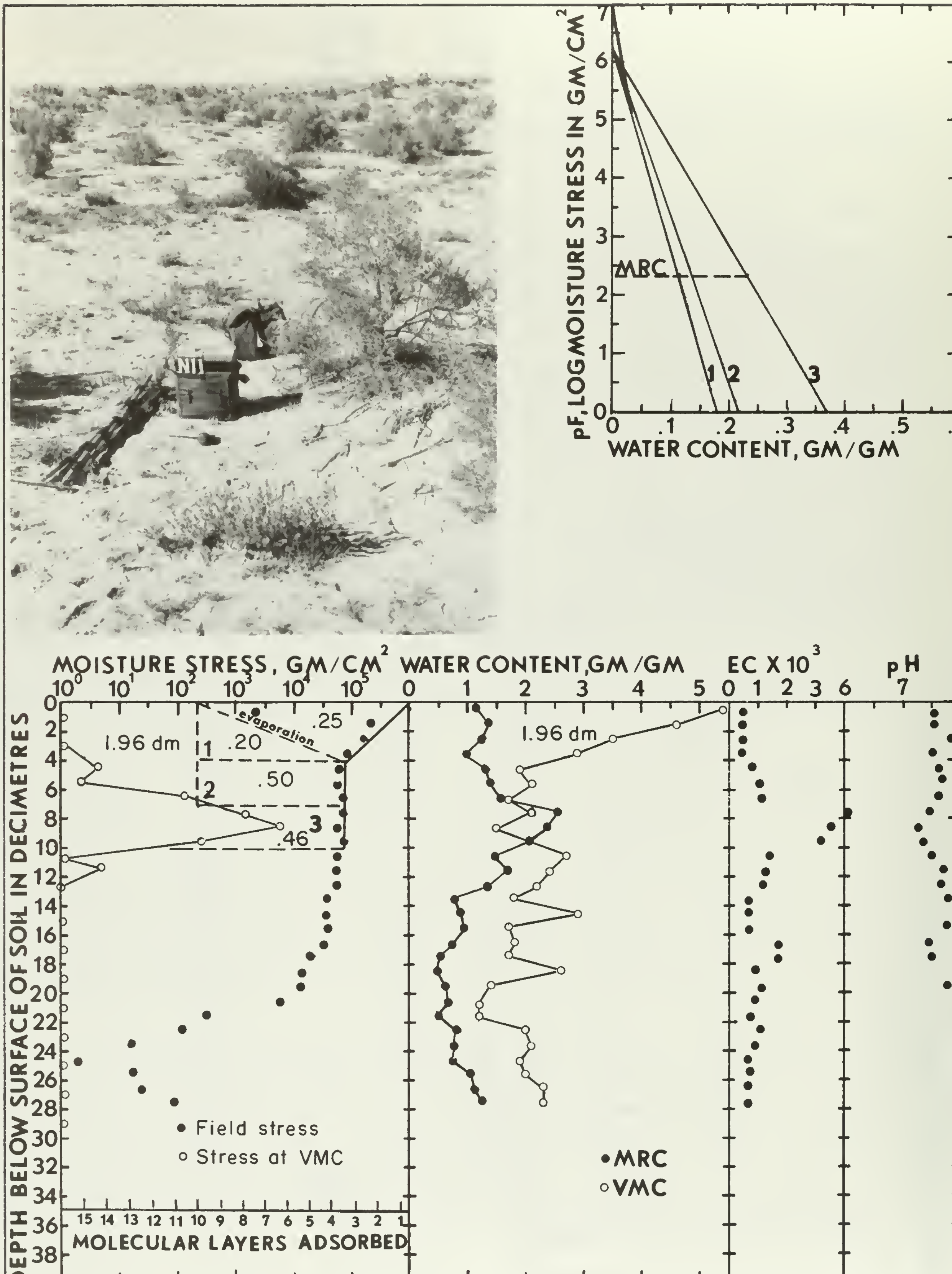


Figure 24.--Soil-water properties of a greasewood site near De-Na-Zin Wash (site 11, fig. 13). The data indicate the presence of ground water in the subsoil.

Recommendations for rehabilitation

Recommendations for rehabilitation can be derived from moisture relationships that have been defined for soils associated with vegetation types in the Bisti West EMRIA study site. Restoration of existing conditions appears to be impractical if not impossible. The species of native vegetation now found in the various habitats are, however, well suited for reseeding rehabilitated areas. The efficiency with which available precipitation is used for plant growth can be enhanced if soil materials are removed, stockpiled, and properly repositioned.

Maximum possible efficiency under present conditions is not achieved at any of the sites sampled, but clues as to how water availability for plant growth could be improved were obtained. Fine-textured residuum is a poor medium for plant growth. However, when it is covered by sandy alluvium or windblown sand of assorted sizes, the moisture is stored in films thicker than normal resulting in the greatest plant growth on the study site.

Optimum soil-moisture conditions and highest efficiency will require the placement of a certain depth of water- or wind-deposited sandy material of assorted sizes over fine-textured alluvium. The depth of the sandy material needed will depend on the MRC. Thus, storage would be provided for all of the soil water that would accumulate during unusually wet periods but still cause temporary storage of readily available water held at stresses less than that at the MRC level of $10^{2.34}$ g/cm^2.

Infiltration into the proper thickness of sandy material could be increased by placing a thin mantle of uniform-sized sand, 5 cm or less thick, on the surface. This material would also help to decrease evaporation losses because film flow to the surface is slower. Too thick a mantle of uniform-sized sand could, however, inhibit seedling establishment.

Generalizations concerning relative depths of assorted-sized sandy material that should be placed over fine-textured residuum can be made from the evidence acquired. The amount of fine-textured residuum that has been stockpiled and the rehabilitation plan would determine the thickness of this type of material placed over unweathered materials. Definition of MRC of the sandy material would not be essential because the MRC levels in the sandy material vary from 8 to 12 percent, with most of the material averaging about 10 percent. Ten molecular layers of water are adsorbed to the surfaces of soil particles at the MRC level. Sixteen molecular layers are the maximum that can be adsorbed as films. This level of storage is achieved when 16 percent moisture is stored in this sandy material. If the material is wetted beyond this level, water either will be retained by capillary forces or accumulate as ground water.

Voids capable of holding the water will develop as these different levels of wetting are achieved. The degrees of wetting will be determined by the depth of sandy material placed over less pervious materials. The minimum level of porosity, encountered at sites where assorted-sized sand was present, is sufficient to accommodate 16 molecular layers of adsorbed water so the moisture content when these voids are filled would be 16 percent. The volume weight, as defined using the relationship between volume weight and VMC illustrated in figure 25, would be 1.86 g/cm^3. The amount of moisture that could be retained at minimum porosity in the sandy material is 0.16 g/g x 1.86 g/cm^3 x 10 cm or 2.98 cm of water each 10 cm depth. Assuming depletion to the level where three molecular layers remain adsorbed, thirteen-sixteenths or about 81 percent of total possible storage would be depleted between maximum and minimum levels assumed. A total of 2.98 x .81 or 2.41 cm could be required to replenish each 10 cm depth. Maximum levels of storage that can be relied upon will be derived from precipitation received during the winter. Between 5.4 and 7.4 cm of water normally precipitate in the period from October through February in the area between Shiprock and Chaco Canyon. An average of 6.4 cm is probably applicable to the study site. Disregarding evaporation, 6.4 cm ÷ 2.41 cm per 10 cm of material or 26.5 cm of sandy material would be required to induce storage of water in films 16 molecular layers thick. This manner of storage would only be temporary because water would drain to depth until only 10 molecular layers remain adsorbed. The average level of storage during the period of drainage would be equivalent to 13 molecular layers of water. About 35 cm (14 in.) of the sandy material would be required to hold the 6.4 cm of water as films that are 13 molecular layers thick. During the period of drainage the water would be subjected to retention forces of less than $10^{2.34}$ g/cm^2 and thus be readily available to vegetation.

Water draining to depth would force soil particles apart, increasing void space available for storage. Water would also slowly infiltrate finer-textured material beneath; and as it does, voids would also increase. As a result, storage in the surface soil would, with time, be less than the original 16 molecular layers. This would provide storage capacity for subsequent storms during periods of greater than normal precipitation.

After alkali sacaton is established during the rehabilitation phase, application of greater depths of sand on the surface would be possible. Deposition of coarse sand will no doubt occur naturally with time as a result of sandy material being reworked by high winds that characteristically occur during March and April.

If rehabilitation utilizing sandy material over fine-textured alluvium cannot be accomplished, management decisions that will necessitate quantitative computations concerning moisture relationships in the fine-textured soils will be required. Minimum VMC in fine-textured soils can

be less than MRC. Infiltration and wetting of these soils will be impeded until VMC have been caused to exceed MRC. As water infiltrates, it will separate soil particles creating voids. Maximum voids will result if water is held on the surface under conditions when a saturated or positive head condition is created. This condition occurs on the surface when melt water is released from a snowpack. It could also be induced by modifying the surface of the soil so that water is retained in furrows or small pits.

VMC will approach the field values for SMC in the topmost horizon. The freezing of saturated soil will increase the volume of voids by approximately an additional 10 percent. Freezing will also improve void stability by facilitating aggregation of soil particles. Voids will exceed saturation to greater depths in areas where water is maintained on the surface for longer periods of time. This could be induced by causing snow to accumulate behind drift fences or by irrigation. If sprinkler irrigation is used, a series of wettings would be required. With each successively longer wetting, total void capacities would increase. The VMC of the soil can be determined by measuring the volume weight and using the relationship in figure 25 between volume weight and VMC. Checking volume weights with depth after each application of water will be essential to determine when the desired VMC has been achieved. Below the saturated zone, water will migrate to depth as capillary water over the surface of adsorbed water. There will be a tendency for void capacities to decrease to the level where only adsorbed water can be retained; and below that depth, a decrease to the MRC level. Below the maximum depth of penetration of liquid water, VMC will be less than MRC.

Drainage to MRC levels will occur readily to depths where MRC has previously been exceeded. When irrigation is withdrawn, the voids created will facilitate infiltration and drainage of water derived from natural precipitation. Depths to which void space should be artificially created will depend on amounts of water naturally available for storage in soils and the MRC of the soil material being managed. Thus, it is useful to have a means of determining the MRC of soil materials. A method for this is given in appendix C.

When the MRC of the Bisti West samples was plotted against its SMC, three district relationships resulted as shown in figure 26A. The three relationships are the result of different kinds of soil materials and illustrate why the materials should be stockpiled separately during mining and used separately during rehabilitation. The eolian sand samples were from the dunes of sites 7 and 10 (figure 13 and table 9). These were plotted on the same line with residual subsoil samples from sites 3, 4, 5, and 6. The samples of alluvial soil containing fragments of weathered coal come from the active profile of site 6, and the samples containing fragments of baked rock came from site 3. Samples that produced the alluvial soils relationship in figure 26 come from the active profiles of all sites except sites 3, 6, 7, and 10.

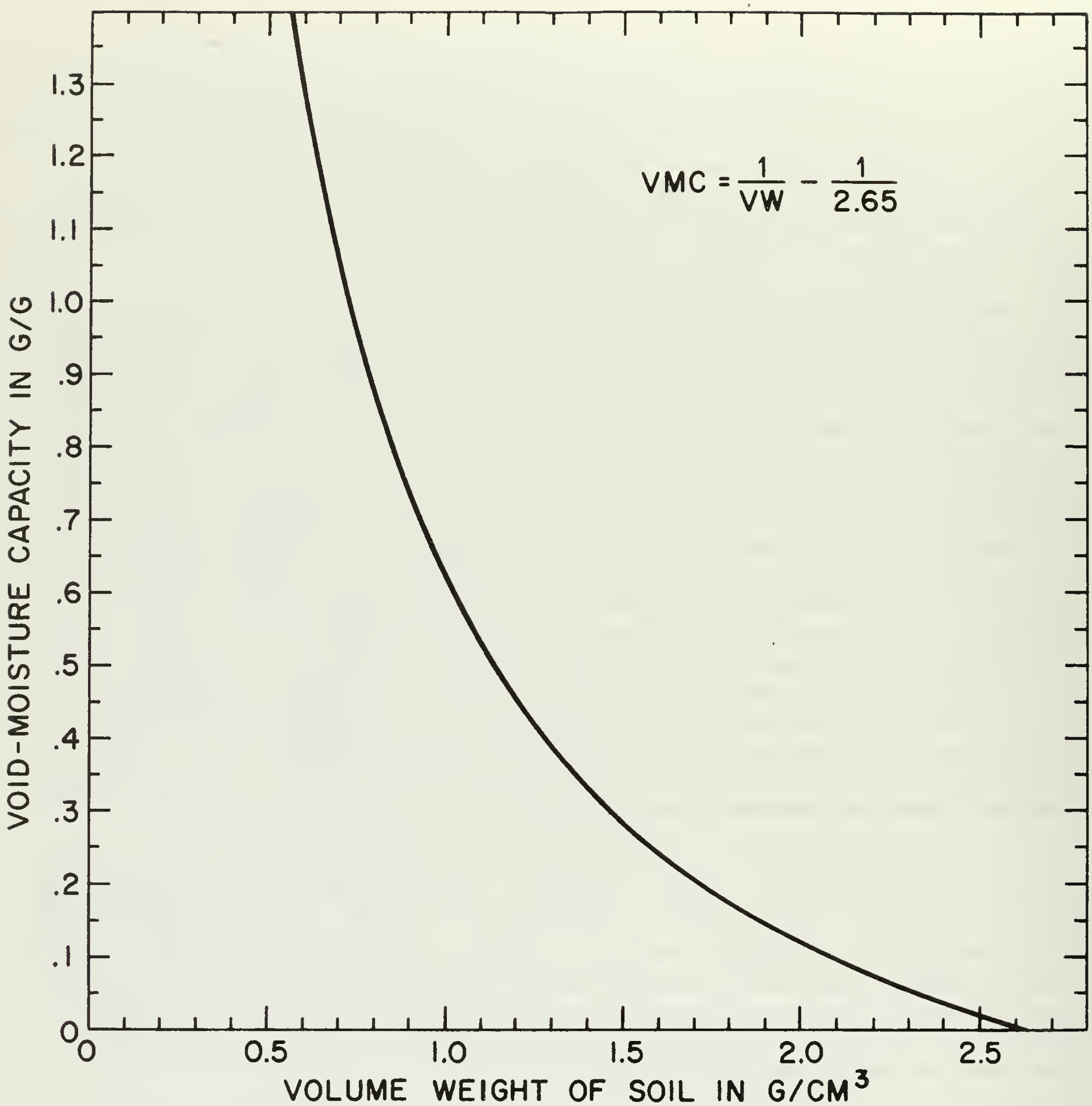


Figure 25.--Relationship between volume weight (VW) and void-moisture capacity (VMC) of soil.

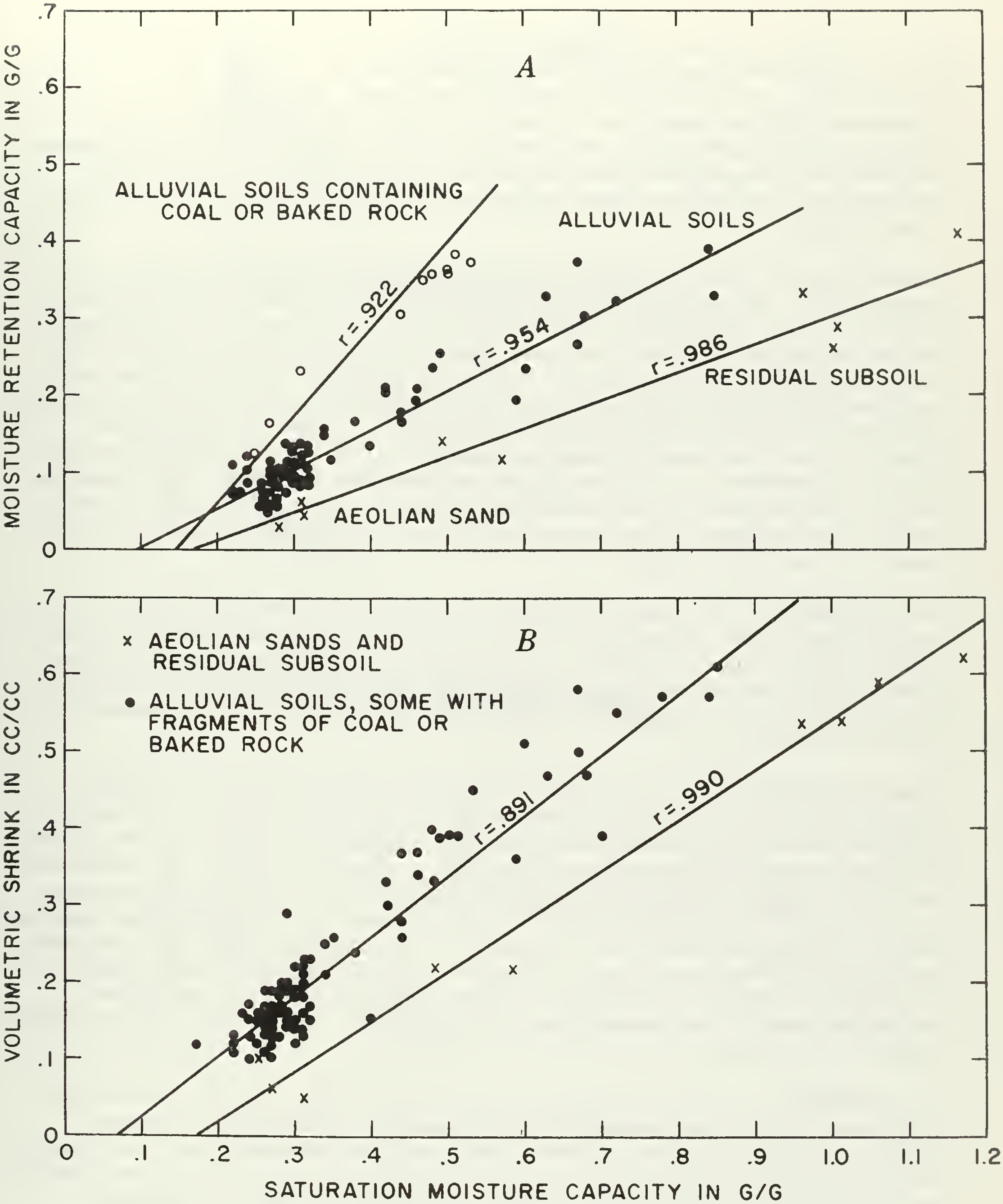


Figure 26.--Relationships of moisture-retention capacity and volumetric shrink to saturation-moisture capacity of soil materials in the Bisti West Study area.

The volumetric shrink or decrease in volume between saturation and air dry of these same samples was plotted against SMC (figure 26B). In that relationship, the values for samples containing coal or baked rock fragments plotted among the values for other alluvial soils and not as a separate relationship such as that shown in figure 26A. This difference indicates that weathered coal and baked rock increase the particle-surface area and MRC of these soils but not the swelling and shrinking capability.

Graphic models that illustrate the differences in water-retention characteristics of the different types of materials are shown in figure 27. Moisture-retention values corresponding to each one-tenth g/g increase in SMC was selected from the three lines in figure 26A as a first step in preparing the graphic models. Then an adsorbed-moisture line and a capillary-moisture curve were drawn for each data group resulting in the families of relationships shown in figure 27. Lines were extended downward from the oven-dry stress level of $10^{6.25}$ g/cm^2 through the set of MRC for each type of material to produce each family of the adsorbed-water relationships. The associated saturation-moisture contents were used as the maximum value on each capillary water curve where it intercepts the horizontal axis.

The resulting three graphs indicate differences in maximum porosity of the different soil materials as indicated by the maximum capillary water contents that occur when they are saturated. The graphs also show the potential of the materials for retaining capillary water as compared to their potential for retaining adsorbed water at any level of moisture-retention force.

Figure 27A shows that the porosity of the eolian sands and residual subsoils and their potential for retaining capillary water is relatively high compared to the water that can be retained as adsorbed films. The alluvial soils are less porous; therefore, their potential for retaining capillary water is much less compared to the water that can be retained as adsorbed films (figure 27B). In the alluvial soils containing weathered coal or weathered baked-rock fragments, the porosity is so low that the potential for retaining capillary water exists only for those soils with low adsorbed-moisture capacities (figure 27C). Also, at the higher retention capacities proportionately less water can be adsorbed, even at saturation, because of the lack of voids.

Establishment of vegetation will be very difficult in the fine-textured soil materials of the badlands and lowlands. Because of the large amounts of particle-surface area, water will be adsorbed as films less than 10 molecular layers thick. The presence of coal and its weathering products in the soil further increases the surface area and further decreases the availability of water. For this reason, soil material contaminated with coal should not be used for rehabilitation. Evaporation is proportionately higher from fine-textured soils than from coarse

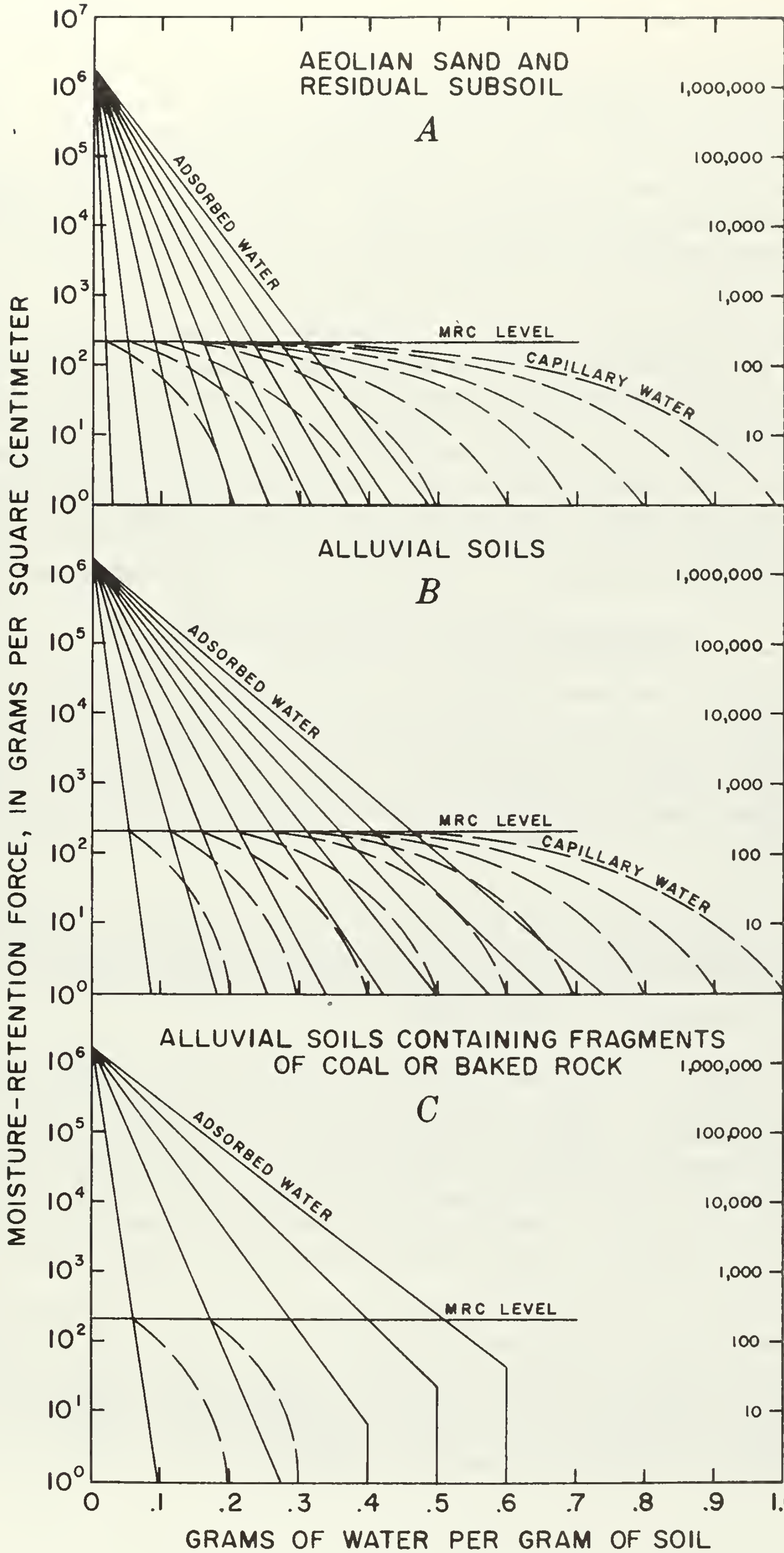


Figure 27.--Relationships between moisture content and moisture-retention force for different kinds of soil materials in the Bisti West Study area.

soils because much of the water is retained near the ground surface where it readily evaporates. The amount of force required to desorb a given quantity of water from a soil increases progressively as the MRC of the soil increases. This is illustrated in figure 28 by data derived from sites where the adsorptive capacity of the soil exceeded the amount of water that actually entered the soil. This illustration demonstrates another reason why fine-textured soils could present problems if used as a medium for plant growth in arid areas such as Bisti West.

The amount of live plant cover is a function of the quantity of water available for depletion from the soil. Relationship between percent plant cover and decimeters of water depleted between maximum and minimum levels of storage is presented in figure 29. The regression coefficient is slightly higher (r = .913) when only water that is transpired is considered. The coefficient is (r = .896) when water that evaporated was included with water that transpired. The relationships could be used to estimate plant cover from a given quantity of water or to estimate available moisture for areas with an established cover.

Infiltration and Soil Detachability

Soil erosion and sediment production involves the interaction of two sets of forces. One set of forces--the erosive agents rainfall and runoff, wind, ice, etc.--cannot be forecast for any given time period at a given site except as probabilities based on past records. The other set of forces--the ability of the soil to resist the actions of the erosive agents--can be defined by properly designed laboratory and field tests.

Detachment and transport of sediment in runoff can occur only when the rate of rainfall (or the snowmelt) exceeds the rate of infiltration. If infiltration rates are known, the magnitude of storm that will produce runoff and erosion can be estimated.

The infiltration rates shown on figure 30 are for the soil mapping units shown on figure 12. These rates were extrapolated from infiltrometer measurements made in 1976 on similar soils at the Kimbeto Wash study site approximately 15 miles to the southeast on this study site. Applicability of these measurements is corroborated by the qualitative descriptions of the soil mapping units (see Soil Inventory, Chapter II) and the soils hydraulic conductivity data of this report (table B-5).

Four infiltrometer measurements were made at 21 soil sampling sites at Kimbeto Wash in 1976 using small single-ring constant-head infiltrometers. Rates were computed for each 5-minute interval, and the near constant rate achieved at the end of 1 hour was assumed as the rate for the measurement. The best three of four measurements at a sampling site were averaged to define the rate for the site.

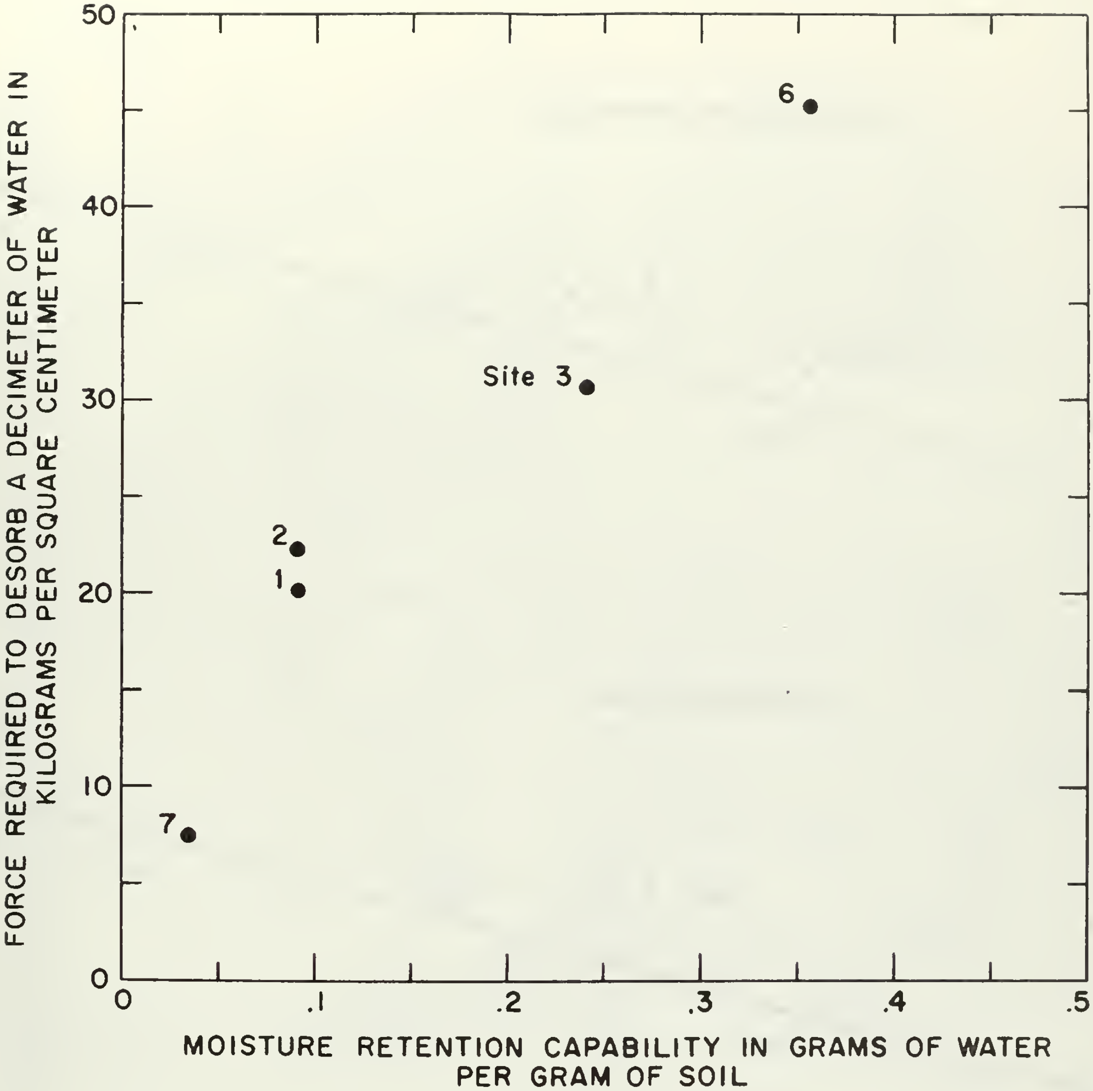


Figure 28.--Relationship between moisture-retention capability and the force required to deplete a decimeter of water from storage in soils of the Bisti West Study area.

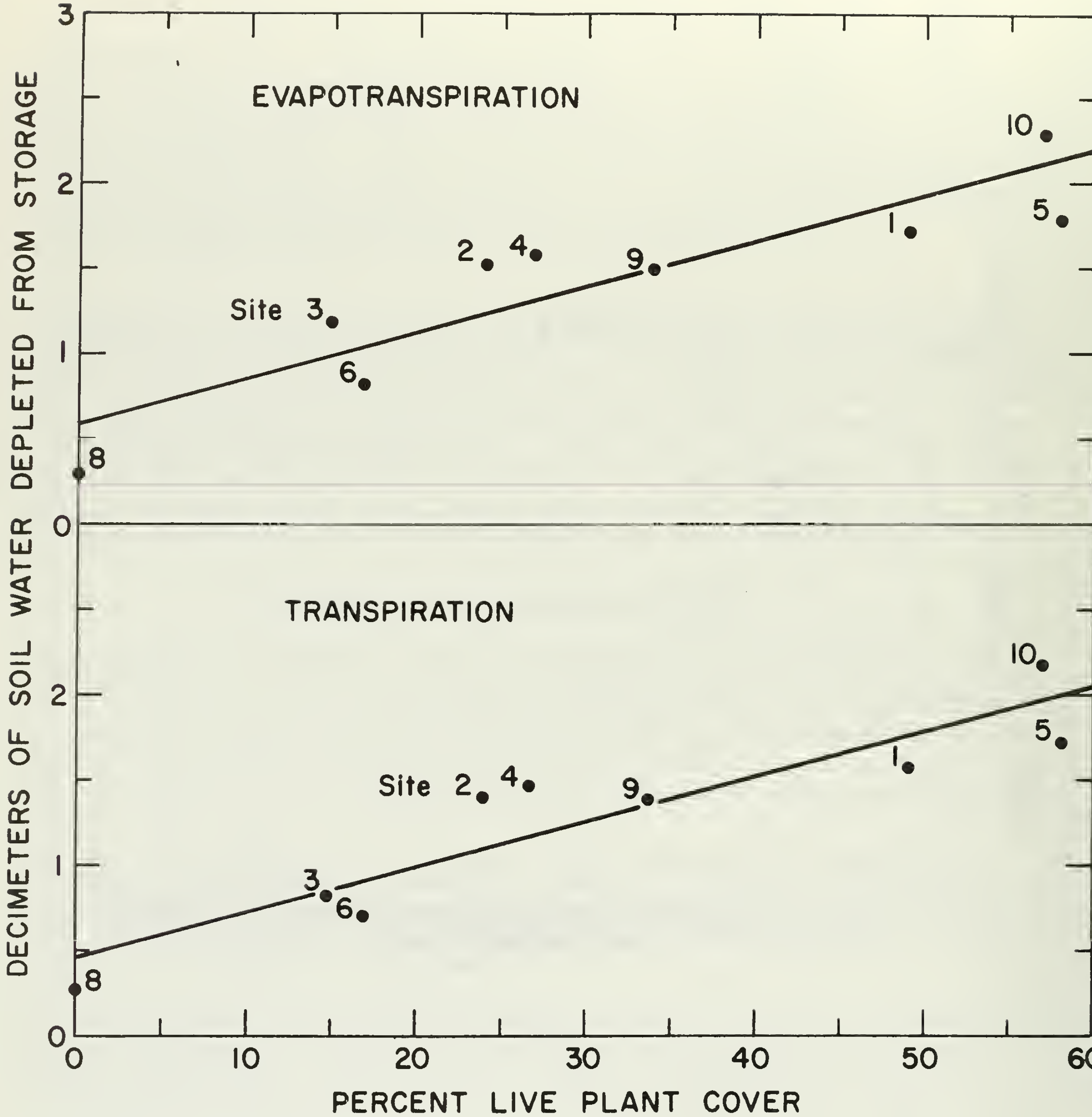
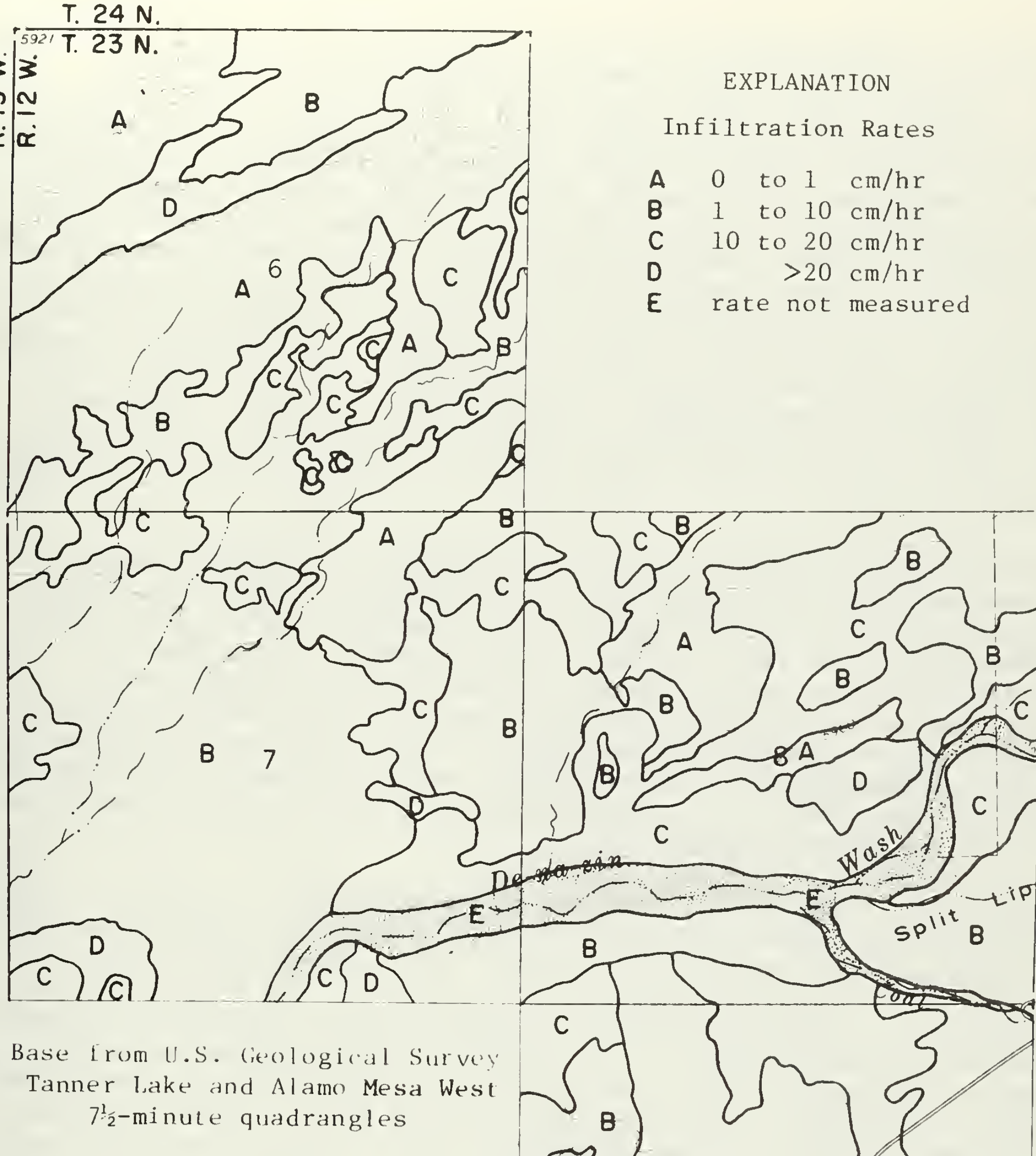


Figure 29.--Relationships of the quantities of water transpired and evapotranspired to the amount of vegetation cover on the sites studied in the Bisti West Study area.



MAP SHOWING APPROXIMATE INFILTRATION RATES FOR SOILS ON THE BISTI WEST STUDY AREA--NEW MEXICO, 1975

FIGURE 30

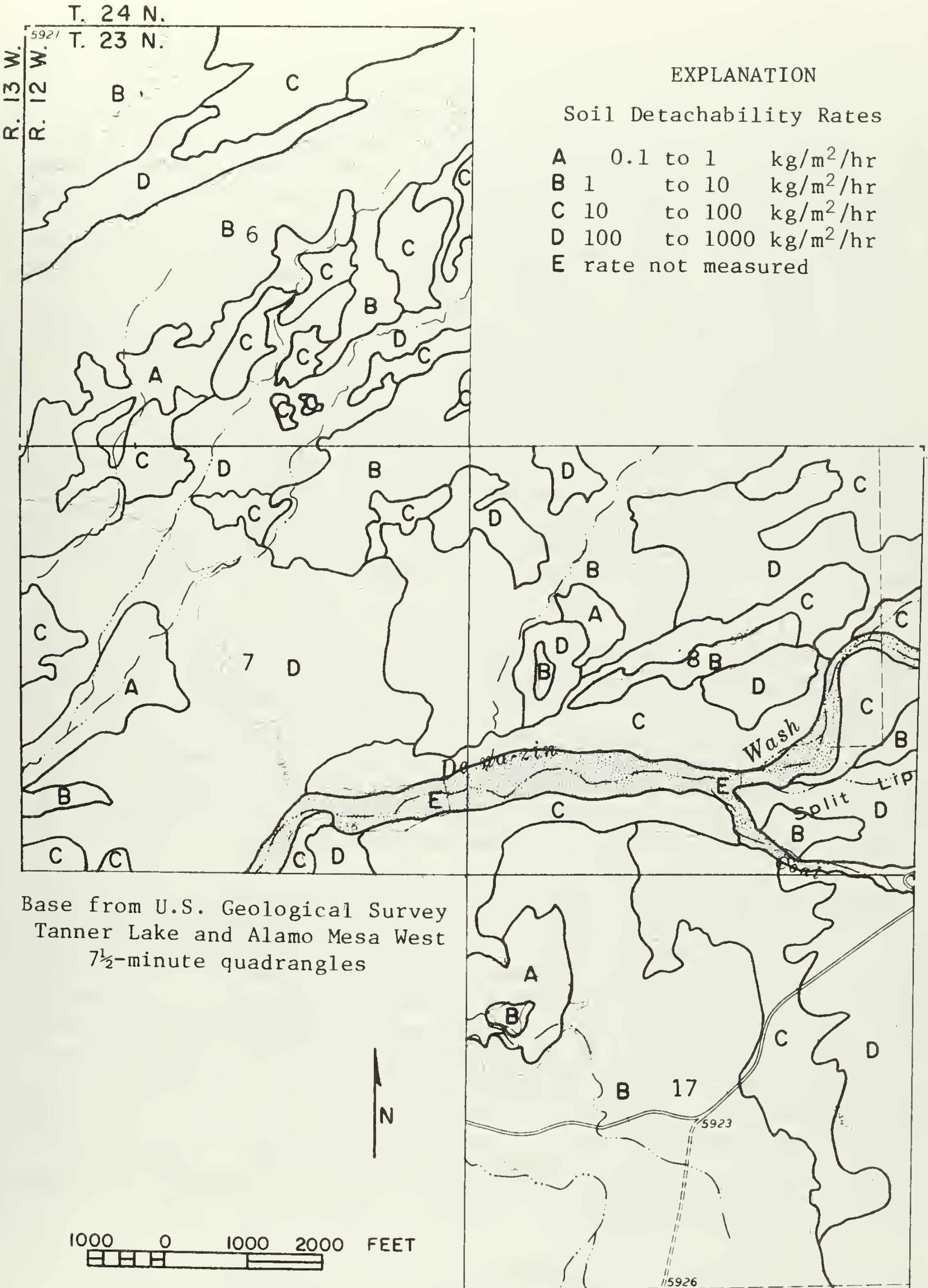
Mixing of the soils during mining and reclamation will probably decrease these rates because structure and root channels will be destroyed. Also, if a soil with a high infiltration rate is placed in a thin layer over a soil with a low infiltration rate, the rate for the combination will approach the lower rate after the moisture deficiency of the top layer is satisfied. For example, 50 cm of dune sand over a typical badland soil material (7001 or 7004 over 7002, figure 12) could absorb approximately 20 cm of water in 1 hour which is more water than produced by a 50-year 24-hour storm in the area. Ten cm of dune sand over a badlands soil would retain about 4 cm of water which about equals the rainfall of a 2-year 24-hour storm in the area. The badland soil material will absorb 1 or 2 cm of water during the first hour of a storm, then the infiltration rate decreases to about 0.5 cm per hour. This means that without a sand top dressing the badland soil material will reject water from most of the storm events and is therefore subject to frequent erosion.

Susceptibility of soils to erosion by flowing water was determined in the laboratory by subjecting samples to controlled erosion forces and measuring the rate of detachment. This procedure does not give actual sediment production from the wide range of erosion events that occur at a site, but it does permit grouping of the soils in relative detachability classes. Remolded samples are used in these tests to simulate the condition of the soils after mining. Tabulated data for soil moisture and detachability at the vegetation sampling sites are included in table C-1. Detachability classifications for the soil mapping units of figure 12 are shown in figure 31.

A comparison of the infiltration and detachability maps (figures 30 and 31) shows that, in general, high infiltration rates are associated with high detachability, and low infiltration rates are associated with low detachability. Where infiltration rates are high, the water from most storm events is absorbed and there is little or no erosion even though detachability rates are high. If soils with low infiltration rates (clays) are placed up slope from soils with high infiltration and detachability rates (sands), severe erosion problems may be caused downslope by overland flow off the less permeable soils. Surface treatments such as pitting or contour furrowing could be used to reduce runoff from flat to moderately sloping areas with clay soils. Erodible soils on the tops of mesas and on dunes have been preserved because there is little or no overland flow to erode them.

Sediment Yields

The sediment yield values presented for this area were derived using a numerical rating method developed by the Pacific Southwest Inter-agency Committee (PSIAC 1968). Although judged to be reasonably accurate, these values should be verified by field measurements.



MAP SHOWING SUSCEPTIBILITY OF SOILS TO DETACHMENT BY FLOWING WATER FOR THE BISTI WEST STUDY AREA--NEW MEXICO, 1975

FIGURE 31

The mapping unit that is the basis of this sediment yield evaluation is the source area which is defined as a small relatively homogenous watershed area that is part of a complete drainage basin. The primary factor used in delineating a source area is landform type. The PSIAC method is used to assess the hydrologic variation of the given landforms as well as to make estimates of sediment yield from them. Numerical ratings are assigned for each of the nine factors of the PSIAC method to representative sediment-source areas in accordance with the degree of influence each factor has on the sediment yield from the area. These nine factors are surface geology, soils, climate, runoff, topography, ground cover, land use, upland erosion and channel erosion, and sediment transport. The method was developed to make broad sediment yield classifications for large areas, such as river subbasins, but Shown (1970) found that the method provides reasonable estimates for small drainage basins (.02 - 7.5 square mile). In applying the method on source areas some adjustments are made because a complete drainage system is not being considered. Alluvial fan and flood plain development are not considered in the topography factor, and sediment transport capabilities are not considered for channels that originate in up slope source areas and that cross through the source area being rated. These factors are taken into account later when making estimates of sediment yields from drainage basins.

Interpretations of color aerial photographs (1:32,000 scale) and black and white photographs (1:12,000 scale) were used to extend the source-area sediment-yield estimates to those areas that were not rated in the field investigation. The slope data were obtained from the 1:24,000 USGS topographic quadrangles. The percent bare soil estimates were based on site measurements reported in the vegetation section of this report. The data were extrapolated from the sites to the remainder of the study site with the aid of the aerial photographs.

The geometry of the active channel was measured at selected cross sections on the study site (table 11 and figure 32) to aid in rating the runoff factor in the PSIAC method and to evaluate flood discharges. The active channel is the lower portion of the channel entrenchment that is actively involved in the transportation of water and sediment during the usual flows, but not the exceptionally high floods. The boundaries of the active channel are relatively permanent, with the sides usually steep and barren, and the top of the channel is where the sides abruptly change to a flatter slope where vegetation may be present. Samples of the bed and bank materials were collected at some of the cross sections for determination of their particle-size distributions. These data along with field observations were used in rating the sediment transport efficiencies of the channels.

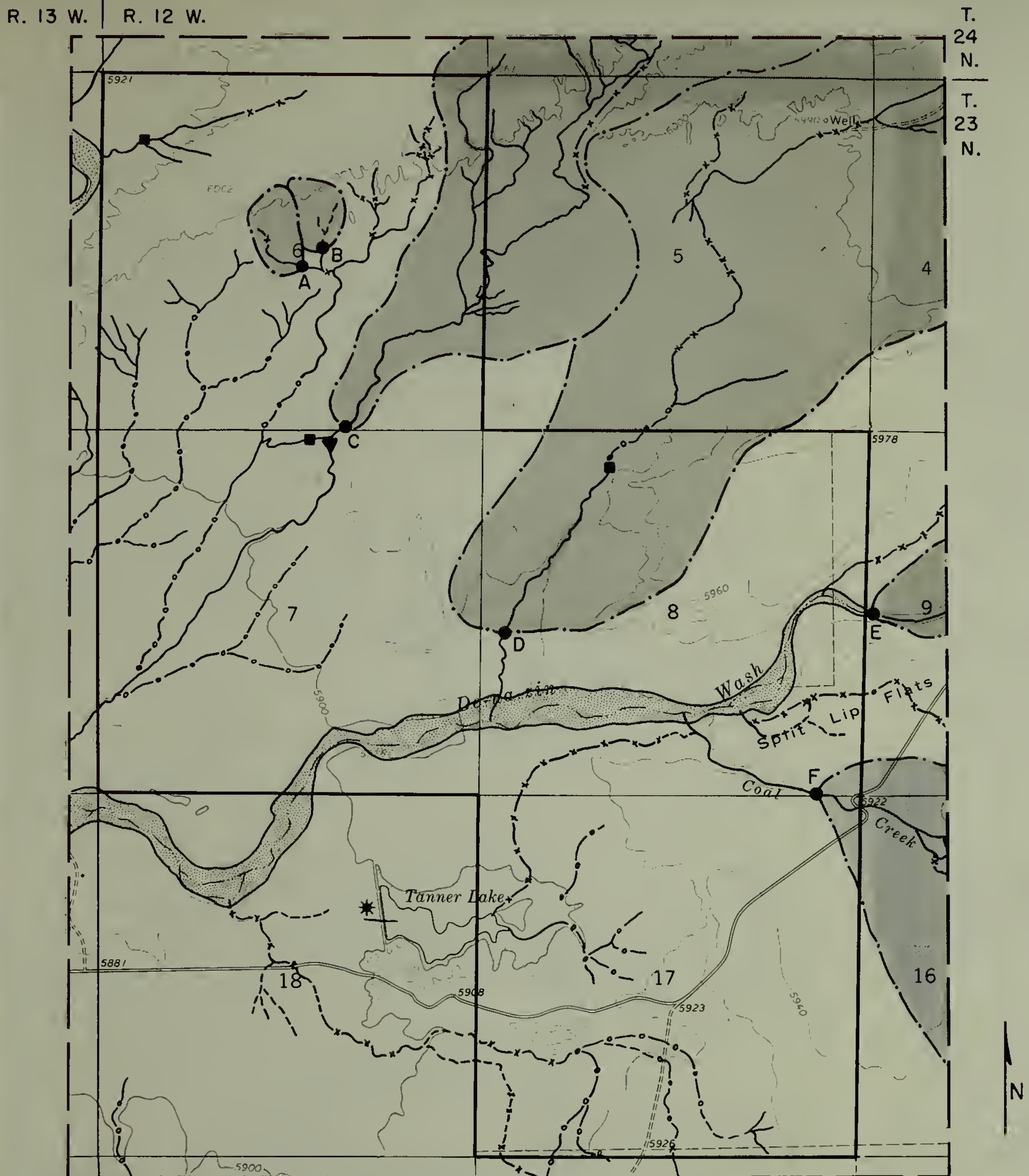
The complete main channel system was classified and mapped according to channel type and condition (figure 32) to aid in assessing channel

Table 11

Channel characteristics at selected locations on the Bisti West Study site July 1975

Channel section[1]	Drainage area (mi^2)	Active channel geometry Width (ft)	Depth (ft)	Gradient (percent)	Channel Material and median grain size (mm) bed	bank	Remarks
A	.03	5.0	.25	2.5	sand	sandy clay	badlands outflow
B	.03	3.5	.15	2.5	sand	sandy clay	badlands outflow
C	4.6	6.5	.5	1.0	sand (1.25)	sandy loam (1.2)	sand bars in channel
D	1.2	7.6	.5	.5	sand, fine gravel	sand	sand bars in channel, some spill into drainage from N.W. during high discharges
E	19.6	55	.25	1.5	sandy clay (.5)	sandy clay (.4)	at stream gage
F	22	55	.6	1.5	sand, fine gravel (.9)	sandy loam (.4)	near stream gage
G	60	180	.75	.5	sandy clay	sandy clay	section located about 1,750 feet downstream from the edge of the mapped area at road crossing.

[1] Locations are shown on Figure 32.



Base from U.S. Geological Survey
Tanner Lake and Alamo Mesa West
7½-minute quadrangles

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Estimated Annual Sediment Yields From Drainage Basins

Basin	Drainage area (mi^2)	Weighted source-area sediment yield (acre-ft/mi^2)	Sediment conveyance factor	Estimated basin sediment yield (acre-ft/mi^2/yr)
A	.03	1.7-2.4	.9	1.5-2.2
B	.03	2.3-3.2	.85	1.9-2.7
C	4.6	1.4-1.9	.85	1.2-1.6
D	1.2	.7-.9	.7	.5-.65
E	19.6	Unmodified PSIAC method used		1-1.4
F	22	Unmodified PSIAC method used		.75-1.1
G	1/ 60	Unmodified PSIAC method used		.8-1.2

1/ Basin G is De-Na-Zin Wash with the selected outlet about 1,750 feet downstream from the edge of mapped area at road crossing. Total drainage area of the basin is 138 square miles, but only about 60 square miles contributes flow.

EXPLANATION

- Raw gullies
- Healed gullies
- Braided channels
- Untrenched channels
- Headcut
- Dam
- A — Outlets of drainage basins for which sediment yield estimates were made and locations where channel measurements were made
- Drainage basin divides
- Boundary of mapped area
- Tanner Lake dam is broken

MAP SHOWING DRAINAGE BASINS AND CHANNEL CLASSIFICATION FOR
BISTI WEST STUDY AREA--NEW MEXICO, 1975

FIGURE 32

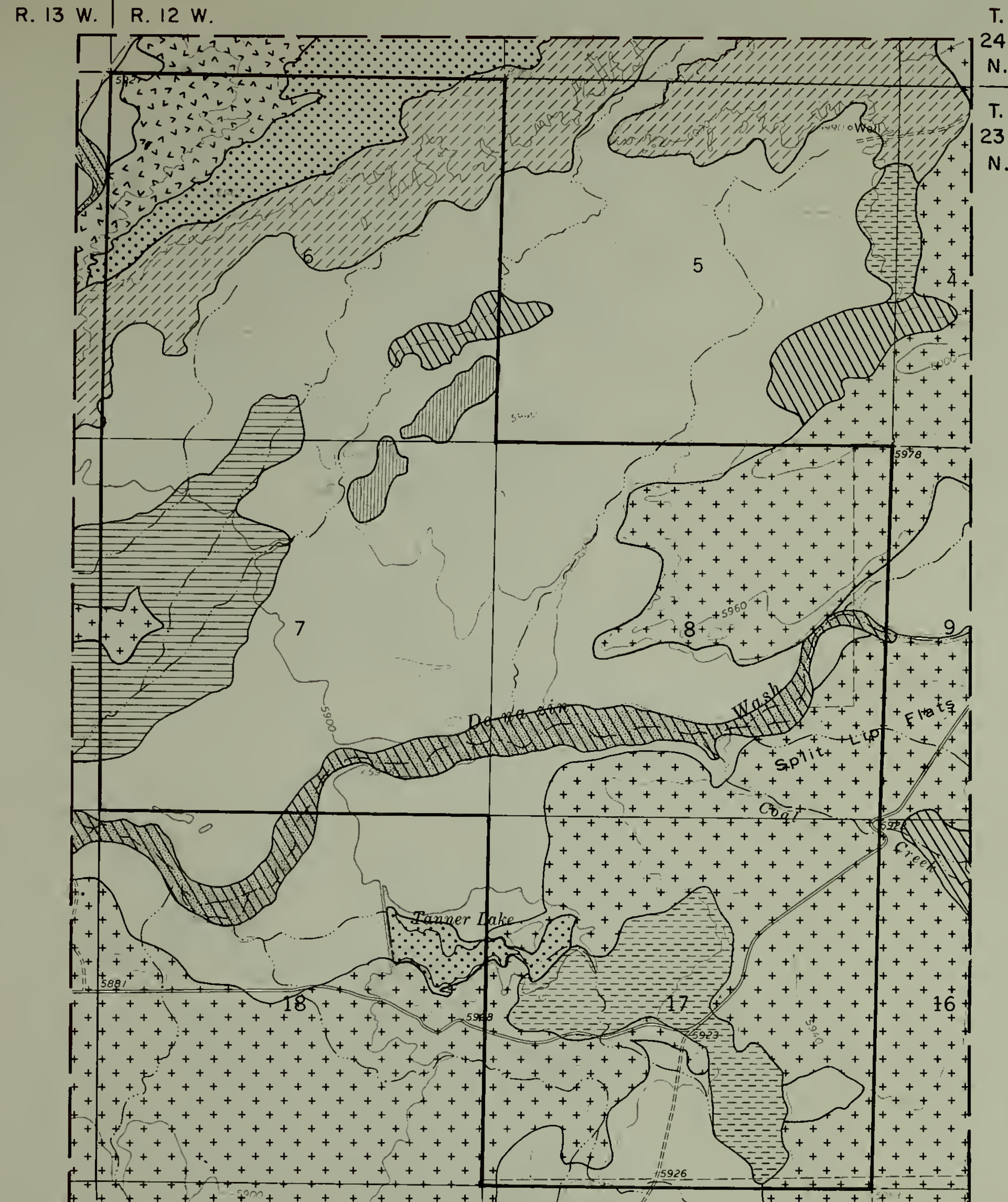
erosion and deposition. The channel classification was done by interpretation of the aerial photography and only those channels that were larger than about fourth order according to Strahler's (1952) classification were delineated. The channel-classification map was used along with the information obtained at cross sections in deriving sediment-conveyance factors which are multiplied by the weighted average source-area sediment yields to obtain estimates of sediment yields from basins. The sediment conveyance factor (SCF) represents that part of the total sediment load entering the main channel and principal tributaries that is transported on through the channel system and not deposited somewhere en route. The method used in assigning the SCF was used previously by Frickel, Shown, and Patton (1975). The method considers the effects on sediment transport of various conditions such as (1) channel width and gradient; (2) whether the channel is gullied or not; (3) size of the bed material and type and density of vegetative cover on the channel bed; (4) intermittent gullies in the channel system; (5) evidence of deposition on the channel beds and on bars, flood plains, or alluvial fans; and (6) deposition on botton lands where flows spread either naturally or because of manmade impoundments or diversions of water.

Source-area sediment yields

Source-area sediment yields on the study site range from low to high as indicated on figure 33. The main interacting factors causing this variation in sediment yields are: (1) different slope gradients, (2) different kinds of surficial geologic materials, and (3) the amount of vegetative cover associated with the different materials. The data in the explanation table on figure 33 show that, in general, the source-area sediment yields increase as the slope gradients increase and the amount of bare soil increases. Regression equations defining these relationships probably would not be too valid because of the variability of slope gradients and the extreme variability of bare soil within each of the sediment yield categories.

Low source-area sediment yields shown on figure 33 occur from the flat to moderately sloping Alamo Mesa, valley-situated alluvial plains, and clinker hills which, in general, are covered with coarse-textured soils or geologic materials which are very permeable. An exception is the areas of fine-textured soils, sparsely covered with saltbush, which are interspersed with low, flat, wind-laid sand deposits on the alluvial plains. These fine-textured soils are very-slowly permeable and are resistant to erosion because they are hard and dispersed. The alluvial plains area, therefore, yield only a small quantity of sediment, most of which is sand that is blown into the channels. The plains function mainly as surfaces of transport for sediment derived from the badland areas upstream and within the plains.

Moderate source-area sediment yields occur from scoured and intensely-gullied alluvial plains, from the small badland hills, and from the



EXPLANATION

	Estimated source-area sediment yields (acre-ft/mi^2/yr	Landform	Slope gradients (percent) Range	Mean	Estimated bare soil (percent) Range	Mean
Low	0-.05	Mesa top			45-64	55
		Low, flat dune	0-1	.9	41-58	50
		Dry lake bed			60	60
	.15-.25	Clinker hills	7-10	8	38	38
		Alluvial plains	.5-1	.8	35-58	40
		Low sand dunes	1-10	4	35-65	45
	.25-.4	Alluvial plains with low sand dunes	1-4	2	41-90	53
Moderate	.4-.65	Scoured alluvial plains	1	1	41-58	50
	.65-.9	Low badland hills	5-10	6	41-90	65
	.9-1.2	Wide sandy channels	.3-.5	.4	100	100
		Gullied alluvial plains	1	1	90	90
		Low badland hills	1-5	3	41-90	65
High	1.2-1.7	Low badland	1-6	3	80-85	82
	1.7-2.3	Badland escarpment	12-28	18	85	85
	2.3-3.2	Badland escarpment	10-40	21	94	94
		Boundary of mapped area				

Base from U.S. Geological Survey
Tanner Lake and Alamo Mesa West
7½-minute quadrangles

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ESTIMATED ANNUAL SOURCE-AREA SEDIMENT YIELDS FOR THE
BISTI WEST STUDY AREA--NEW MEXICO, 1975

FIGURE 33

banks of De-Na-Zin and Alamo Washes. High sediment yields occur from the steep badlands which are characterized by shaley geologic materials, extremely sparse vegetation, and a very high density of rills and small gullies. Highest yields occur from the southeast-facing escarpment on the south side of Alamo Mesa which is the steepest badland area.

Channel erosion on the study site is variable as can be inferred from the channel classification information shown on figure 32. More channel erosion is occurring along the tributaries that drain into De-Na-Zin Wash from the north than from drainages that drain from the south with the exception of Coal Creek because more of the channels north of De-Na-Zin Wash are raw gullies than those south of the wash. There is a small amount of bank erosion along most of the raw gullies, and there is some erosion at each headcut. The rate of advance at most of these headcuts is apparently a few feet per year at most. In addition to those headcuts indicated on figure 32, there is usually a headcut at the head of each raw gully. There is no erosion in untrenched channels or along healed gullies, some of which probably are slowly filling with sediment. There is some erosion associated with braided channels, but this is probably balanced by deposition that is occurring on fan-like deposits between the braids. Bank-cutting is slow in the wind-laid deposits along De-Na-Zin and Alamo Washes which results in the sediment yield shown on figure 33 for these channels. The streambed elevations of these washes appear to be relatively stable. Some bed material undoubtedly is scoured during the main part of each flow, but this is balanced by deposition during the recession of each flow.

Untrenched channels in the upper reaches of the drainage network were not delineated on figure 32 as was not the untrenched, spreading reach of the channel that enters the study site near the southwest corner of section 18.

Basin sediment yields

The estimated sediment yields from the drainage basins, as shown in the table on figure 32, tend to be high, which is typical of arid areas in the southwestern United States wherever the bedrock is shaley. Sediment yields per unit area tend to decrease as the basin size increases because of two main factors: (1) intense thunderstorms, which are limited in areal coverage, may completely cover a small basin but cover only part of a larger basin and (2) as basin size increases the amount of slight and moderate sloping area increases with respect to the amount of steep areas in the basin. For example basin G is larger than basin F, but their sediment yields are similar because basin G has a greater percentage of its area composed of badlands.

The sediment yields for basins A through D correlate with the weighted average source-area sediment yields, and thus are in accord with the relief and kinds of surficial geologic material and the associated

amount of vegetative cover in those basins. The sediment conveyance factors for the study site are generally high indicating that most of the sediment that leaves the source areas is being moved through the main channels and out of the basins. This is evidenced by the predominance of sand and small gravel and the lack of silt and clay on the barren channel beds at the mouths of the basins as shown in table 11. Basin D has the lowest sediment conveyance factor because it has the highest percentage of channel length in the healed gully, braided channel and untrenched channel categories (figure 32).

Effects of mining and recommendations

Without reference to a mining plan for an area, it is difficult to assess the effects of mining on sediment yield. Nonetheless, if the area is mined, it is assumed that the area will be rehabilitated for rangeland and watershed uses and conservation measures will be necessary to control erosion and minimize the increase of sediment yield from the area.

It is assumed that only the alluvial plains and flat dunes area north of De-Na-Zin Wash would be mined and not the badlands escarpment and that mining would proceed parallel to and northward from near the wash. Prior to mining, consideration should be given to stockpiling the sandy materials from the study site for use as topping on the shaped spoil. The sandy materials are permeable and produce more vegetative cover than any of the other soil materials on the study site and, therefore, would make the best growth media for rehabilitation.

During mining, it is assumed that streamflow that arises along the badland escarpment and on the upstream alluvial plains would be diverted around the mine. Prior to mining, however, consideration should be given to alternatives for controlling streamflow that will arise in the badland escarpment <u>after</u> mining and rehabilitation are completed. One alternative would be to excavate a permanent diversion channel along the base of the badland escarpment from the NE 1/4 of section 5 over to Alamo Wash. There would be some erosion and increased sediment yield for a few years until the diversion channel stabilizes. This alternative does present a hazard in that eventually the channel may meander to a mined area. Then, after the last-cut pit of the mine fills with sediment, which may take several hundred years, the streams may flow across the mined area carving their own channels and drastically increasing sediment yields to De-Na-Zin Wash. Another alternative would be to construct wide, laterally flat drainageways in the shaped topography during rehabilitation procedure to accomodate flows arising upstream from the mine. There would probably be some erosion in the drainageways for a few years until they stabilize.

During the shaping of the postmining landscape, the construction of small flat areas and closed basins, a few acres in size, will help to

minimize erosion on the mined area. If this is done in addition to placing sandy material on the surface, seeding grasses and sprinkler irrigating with impounded surface waters for about 2 years, estimated sediment yields from the mined area probably will not be more than about 1 acre-foot per square mile. Furthermore, after vegetation is established and the sandy material and the drainageways have stabilized, sediment yields may not be greater than before mining.

Hydrology and Water Supply

Surface Water

Quantity. For the 1975 water year, De-Na-Zin Wash near Bisti, New Mexico, had an estimated runoff of 400 acre-feet. Runoff from tributaries within the study area was estimated to be 4 acre-feet per square mile (acre-ft/mi^2) for the sandy-soil areas, estimated from channel geometry peak flow data for small channels in the study area, and from 20 to 40 acre-ft/mi^2 for badlands areas, from one year of data for Hunter Wash. The sediment yield from the study area ranged from less than .01 acre-foot per square mile per year (acre-ft/mi^2/yr) for sandy areas to 3 to 5 acre-ft/mi^2/yr for the badlands.

Data to be published in the report, "Water Resources Data for New Mexico" (1975) for Hunter Wash and Hunter Tributary were used to assist with these estimates.

The stream gaging station and automatic pump sampler of the outflow measuring point in De-Na-Zin Wash were installed in October 1975. The continuously operating gage at this station recorded no flow events from October 1975 to March 1976. Also, the nearby Hunter Wash gage recorded no significant flow for this period; however, six local rainstorms during July 1975 to September 1975 recorded greater than 100 cubic feet per second (ft^3/s) of flow at the Hunter Wash gage. All of these storms are presumed to have generated some flow at the gage site in De-Na-Zin Wash. The rain gages in the area indicate that precipitation was about 7 inches for the year October 1974 to September 1975, with about 50 percent of the precipitation falling between July and September. Precipitation from October 1975 to April 1976 in the area was about 2 inches. Average annual precipitation for the area is about 7 inches. The arroyos in this general area flow sporadically from localized, short duration, high-intensity storms, usually during the summer and early autumn. The arroyos are normally dry the remainder of the year.

Estimates for peak flows and their recurrence intervals for selected sites are given in table 12 and their respective locations are shown in figure 34. These data are estimated by the channel geometry techniques explained by Hedman (1970) and Moore (1968). Several additional sites were examined at the study site, but overflow between channels made the data difficult to interpret.

Table 12
Bisti West Reclamation Study Site Peak Discharge Estimates

Map No.	Station or Site Name	Drainage Area (mi^2)	2-yr peak flow (ft^3/s)	5-yr peak flow (ft^3/s)	10-yr peak flow (ft^3/s)	25-yr peak flow (ft^3/s)	50-yr peak flow (ft^3/s)	Remarks
37	Coal Creek above Tanner Lake	100*	1,360	2,850	4,230	6,250	7,820	*At high discharges there are overflows into Tanner Lake.
36	De-Na-Zin above Tanner Lake	19.6	1,380	2,890	4,300	6,330	7,920	At gaged site.
C1	Bad Lands out-flow	0.027	14	41	73	133	197	Near simulated rain test plots.
C2	Band lands out flow	.03	25	73	125	223	322	Do.
C3	De-Na-Zin at Tanner Lake ford	138	9,700	17,500	24,200	32,500	37,900	Represents most of the flow at De-Na-Zin near Bisti Gage except Alamo Wash.
C4	Trib. to De-Na-Zin N. of Tanner Lake	1.23*	49	132	222	385	543	*Some spill into drainage from N.W. at high discharges.

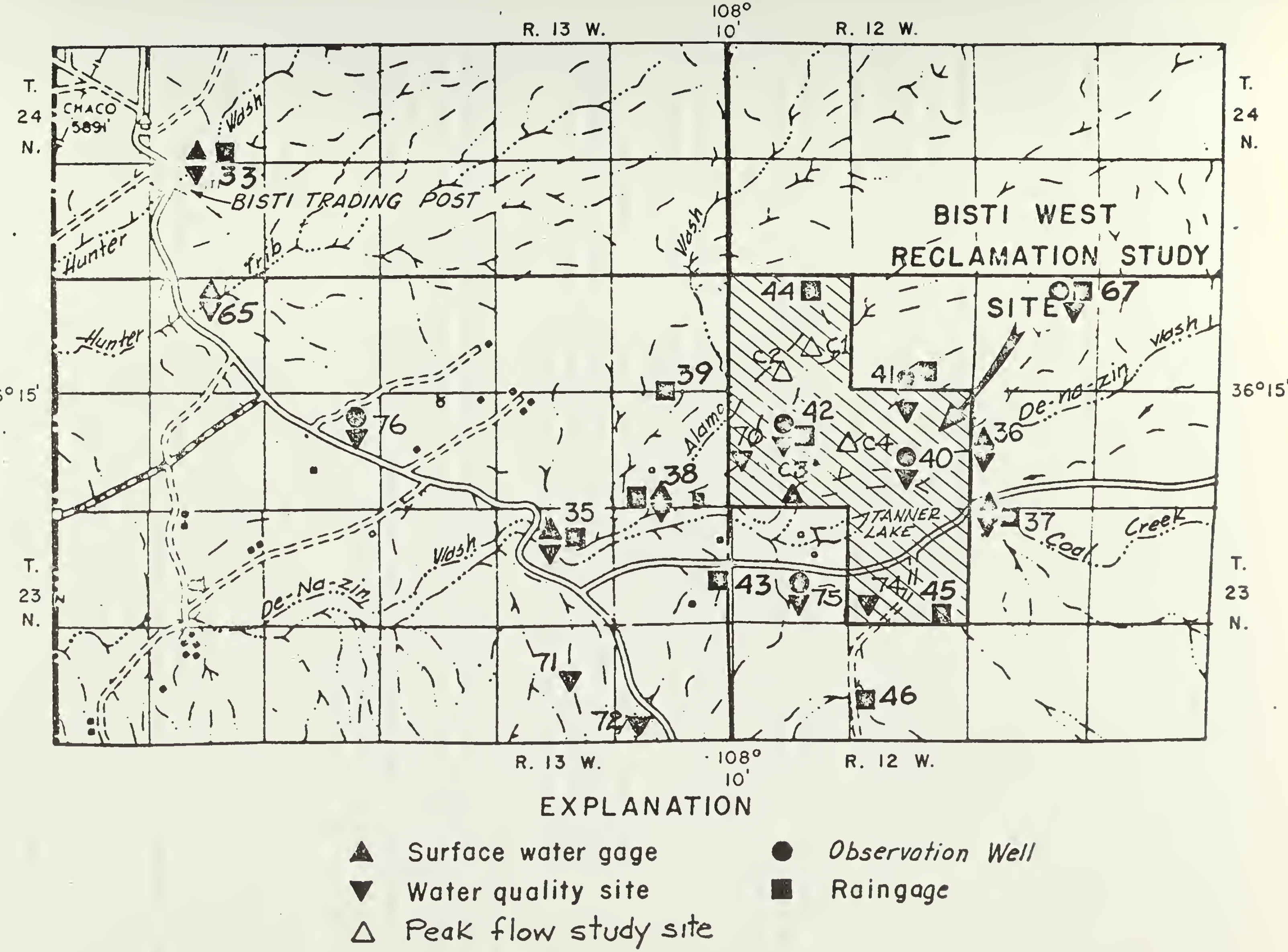

Figure 34.-- Bisti West coal study area.

Tanner Lake is a dry lakebed in the study area. It is a former manmade reservoir created by damming a tributary arroyo to De-Na-Zin Wash in the broad flat lowlands adjacent to De-Na-Zin Wash. It was designed to capture ephemeral flows from its arroyo and overflows from De-Na-Zin Wash. The 15-foot-high dam is breached, but an inspection of the now dry reservoir found no evidence that the highest stage in the reservoir was ever near the crest of the dam. The dam appears to have failed from structural weakness at its release gate rather than from high stage or storm overflow stresses. The lake's storage capacity is crudely estimated to be several hundred acre-feet.

Suspended sediment from runoff is deposited on the lakebed to a maximum depth of about 5 feet and consists mostly of fine silts. Vegetation grows on the periphery of the lakebed, but is absent on the lowest part of the lakebed near the dam. This indicates that growth inhibiting high concentrations of salts are collected by evaporation in this low area.

Quality. Several quality-of-water samples from arroyos and stock ponds within and near the Bisti study area were collected during field reconnaissance trips. The suspended sediment analyses are shown in table F-1 and the chemical analyses of selected samples are shown in table F-2. Some water samples were collected by single-stage samplers installed in the arroyos, but they were used primarily for suspended sediment analyses. The small volumes collected were not adequate for chemical analyses. The single-stage samplers have been redesigned to collect larger samples using chemically inert plastic materials instead of metal and glass. Future samples collected with these single-stage samplers will be analyzed for chemical constituents.

Water quality of the first arroyo flows of the spring or early summer is usually poor because of fall and winter accumulations of soluble materials originating from weathered soils and rock, from evaporation of saline water, and from animal and plant wastes. After the initial flushing, the quality of the water improves progressively through the storm season unless extended intermediate dry periods allow soluble materials to accumulate on the watershed.

During a storm event, the greatest concentrations of suspended and dissolved material are carried during the rising stage. The water quality usually improves thereafter until the final trickles, containing higher dissolved concentrations from bank storage, seep back into the channel. All surface flows in this area seem to be accompanied by very fine suspended sediments which settle out very slowly. Undisturbed samples in the laboratory remain turbid for several months. The fine suspension may affect the chemical quality by eventually dissolving or by ion exchange on suspended sediment surfaces. The dissolved solids concentration of the arroyo flows range from 300 milligrams per liter (mg/l) to about 2,000 mg/l. The dominant constituents are sodium, sulfate, and bicarbonate in that order. Moderate to high levels of

boron, iron, fluoride, and nitrate are also found. Some of the concentration levels may be harmful to certain plants or animals. Calcium, magnesium, potassium, chloride, and silica concentrations are comparatively low. Almost invariably trace, but insignificant, levels of arsenic, selenium, phosphorous, and mercury were found.

Some of the surface runoff is trapped in small natural depressions or impounded in manmade stock ponds. The trapped or impounded water may be collected from one or several flow events, and the water quality in the ponds would be an average composition of the collected flows, with changes caused by evaporation or biological activity in the ponds. Some of the water is consumed by livestock and some infiltrates into the ground, but most of the water is lost by evaporation. Salts are concentrated during evaporation in the stock ponds. A dissolved solids concentration of about 3,000 mg/l was measured in a nearby shallow stock pond. Fine suspended sediment in a pond will reduce evaporation rates by reflecting sunlight and by inhibiting sunlight penetration into the body of water. The fine suspension may also reduce infiltration rates by lining the pond bottom with a clay layer upon settling or by filling pore spaces while filtering through the soil. Proportionately higher concentrations of all major constituents are found in impounded water when compared against runoff water. Higher values of nitrates and organic carbon are found in some shallow ponds and are attributed to decaying vegetation and wastes from livestock using the ponds.

Surface water used after settling out of much of the suspended sediment and before prolonged exposure to evaporation is probably satisfactory for irrigation purposes. Impounded waters with salts concentrated by considerable evaporation would be less suitable because of their high sodium content and high dissolved solids concentration coupled with low calcium and magnesium. Waters of this composition when applied to the soils would change the chemical and physical properties of the soils by decreasing infiltration rates of water through the soils, thus inhibiting the feeding of water to plants and the downward leaching of phytotoxic accumulations of salts from the root zones of plants. The soils may eventually become totally impermeable to percolation of water into the ground if this type of water is applied persistently.

Selected samples were analyzed for other chemical constituents, including trace elements, nutrients, and radioactivity, which appear in table F-2. Results show that for most of these samples constituents were either not detected in the samples or were present at very low levels. Certain of these constituents, such as mercury or arsenic, are analyzed because of environmental concern regarding the presence of these constituents in water supplies.

Suspended sediment concentrations determined from samples captured mostly by the single stage samplers from the De-Na-Zin Wash and Hunter Wash watersheds were in the 4,000 mg/l to 25,000 mg/l range. The higher concentrations were found in Hunter Wash which drains a higher percentage of badlands areas; whereas, De-Na-Zin Wash, which drains a higher percentage of sandy soils, yielded lower suspended sediment concentrations. De-Na-Zin Wash drains some areas that are comparatively more sandy. The percentages of fine materials in most samples whether from badlands or sandy areas were almost always greater than 95 percent of the total weight of suspended sediments in the samples. Fine materials are clays and silts with particle diameters of less than 62 microns. High suspended sediment concentrations may be found throughout a flow event because of the high percentage of the more easily suspended fine material.

Ground Water

The ground water-bearing units in the Bisti EMRIA study area are, in order of increasing depth, the Kirtland Shale, Fruitland Formation, Pictured Cliff Sandstone, Cliffhouse Sandstone, Menefee Formation (?), Point Lookout Sandstone, Gallup Sandstone, Morrison Formation, and Entrada Sandstone. Surficial and alluvial deposits including those in arroyo valleys are considered to be a small but important source of ground water supply. These deposits are relatively thin and localized along the valleys of arroyos and washes. However, the quality of the water in these surficial and alluvial deposits is generally better than the quality of water in the deeper units. This limited shallow supply is usually the most chemically suitable ground water supply available for irrigation use.

Ground water information in the study area is very sparse, but an attempt was made to construct potentiometric surface contours for each of the above units. Figures F-1 through F-7 show these contours with locations of nearby wells and specific conductance readings of water from these wells. Table F-3 summarizes the hydrologic information from these wells. Table F-4 gives chemical quality data for selected wells in the area. The information in these figures and tables is applicable to the area surrounding the Bisti reclamation study site. Data within the study site are either nonexistent or insufficient for the deeper water-bearing units for accurate evaluation. Any deviations from the general patterns within the specific study site cannot be determined without additional drilling in the study site.

Overburden materials are in the Kirtland Shale and the Fruitland Formation; the latter unit also contains the strippable coal. The Pictured Cliffs Formation is the geologic unit directly underlying this coal. Mining impacts on the subsurface water supply would be primarily within these water-bearing units. The different water-bearing units do not appear to be interconnected; lack of connection is probably due to numerous, intermediate impermeable layers of clays and shales. Although the Kirtland Shale, Fruitland Formation, and Pictured Cliffs Sandstone are water-bearing units, they are inferior sources for water supplies because of their poor yields and poor water quality. The three water observation wells drilled and completed in the Pictured Cliffs Sandstone below the coal on the Bisti EMRIA study site show that the interval from immediately below the coal to about 200 feet below the coal produces very little water, and the water is very saline. Dissolved solids concentration of samples collected from those wells were between 3,000 mg/l to 4,000 mg/l. Principal constituents were sodium and sulfate.

The BIA windmill stock well 19-507 at Tanner Lake produces less than 20 gallons per minute of water from the Cliffhouse Formation. The water is brackish and contains 2,150 mg/l of dissolved solids of which sodium, sulfate, and bicarbonate ions predominate. Water from this well is accompanied by a dark, oily substance. The water is used to water livestock after separation of the oily substance.

A gas and oil test well about 3 miles northeast of Tanner Lake was drilled into the Point Lookout Formation. It was converted into an artesian flowing water well for livestock. Like the above BIA well, a dark, oily substance accompanies the water. The water is saline and contains over 7,000 mg/l dissolved solids, principally sodium, chloride, and bicarbonate. This water would not be suitable for irrigation use either.

The ground water supply in the Morrison Formation may be a potential supply for mining reclamation and rehabilitation. Wells tested in this formation show yields greater than 500 gallons per minute (gal/min) but of inconsistent water quality. The El Paso Natural Gas Company's Burnham water well No. 1 completed in the Morrison Formation at a site southwest of Bisti produced water with dissolved solids concentration of less than 1,000 mg/l. The water would probably be chemically suitable for irrigation if applied on permeable soils with adequate drainage. However, early tests performed in the nearby BLM Foshay well indicated that the water tested from the same formation is very saline. More study is needed on the Morrison Formation to draw better conclusions on its water quality.

Water quality in the Menefee Formation, Gallup Sandstone, and Entrada Sandstone is probably very saline from indications of tests on nearby wells. The water quality also seems to be poorer farther down dip or

down the hydraulic gradient of a formation. Better water seems to appear nearer the formation outcrops. Chemical analyses show that many trace elements, nutrients, and radiochemicals are either absent or present in trace concentrations.

Evaluation of available water supply for use in revegetation */

Demand. Revegetation activities for the surface-mined area at the Navajo coal mine of Utah International Incorporated were observed. About 15 inches of irrigation water is applied in the first year of revegetation, followed by one irrigation the second year estimated to be about 2 inches. These rates were used in estimating the possible demand at Bisti West. Use of these rates does not mean that reclamation has been accomplished at the Navajo mine in 2 years with this amount of water. */

In order to estimate possible irrigation requirements for the Bisti West study site, it was assumed that 300 acres would be mined and reclaimed each year, based on mining plans at the Navajo mine. The actual acreage figure for the study site would depend on its own final mining plan, however. If the site is only partially revegetated, these could be maximum irrigation requirements. Using the 300-acre figure, 375 acre-feet of water would be required the first year. Thereafter, the annual requirement would be 50 acre-feet (2 inches on an old 300 acres) plus 375 acre-feet (on a new 300 acres), for a total of 425 acre-feet on 600 acres per year. These requirements do not include storage or transmission losses.

There are four sections at Bisti West, or 2,560 acres. If the total area is mined at the rate of 300 acres per year, the area would be mined in 8.5 years. The revegetation program would end 11 years after mining begins and would require a total of 3,630 acre-feet over the 11-year period, at a maximum rate of 425 acre-feet annually.

Supply. The following sources of water were considered:

1. Local surface waters
2. San Juan River
   (a) Navajo Indian Irrigation Project
      (1) Diversion
      (2) Return flows
   (b) Direct diversion
3. Subsurface water

*/ This subsection prepared by BR. See Partial Revegetation, Chapter IV, for a discussion of the pros and cons of irrigation use in reclamation of areas like the study site.

Use of local surface waters would require the construction of a dam and reservoir. Because of erratic precipitation patterns and evaporation rates, the reservoir should have a capacity of about 1,500 acre-feet, equal to a 3-year supply of irrigation water plus allowances for sedimentation and evaporation. It is not known whether a favorable dam and reservoir site exists locally. However, Tanner Lake is a defunct reservoir partially within the study site (see figure 4 and the previous subsection on Surface Water). It has a capacity of roughly several hundred acre-feet. The breached dam could possibly be repaired. The reservoir could then provide partial storage for reclamation purposes.

Statements on long-term surface water flow values cannot be made at this time because of insufficient data. For the 1975 water year, however, De-Na-Zin Wash near the study site had an estimated runoff of 400 acre-feet based on indirect measurements using channel geometry techniques. This runoff is composed of tributaries within the study area, which was estimated to be 4 acre-feet per square mile for the sandy-soil areas and from 20 to 40 acre-feet per square mile for badlands areas.

Surface waters of the area appear suitable for limited irrigation use, such as the 2-year irrigation period described above. If surface water use becomes a reality, this preliminary appraisal of the suitability of these waters should be confirmed, taking into account plants to be grown, climate, and the interaction and effect of the water on the soil.

Because storage of local surface waters could affect downstream users, the question of rights to these waters must be investigated.

Two alternatives utilizing the San Juan River may be possible. Discussions with Navajo Indian Irrigation Project (NIIP) officials indicate it would be possible to divert water from Navajo Reservoir, on the San Juan River, and transport it through NIIP facilities to the NIIP Burnham lateral, about 8 miles northwest of the study site, if there were no interference with the NIIP irrigation schedule. A pipeline and terminal storage would be required, the latter because NIIP facilities are fully utilized from June 21 through July 20. A pipeline easement would also be required; there are indications that obtaining it will be a problem. This source of water should be adequate to meet Bisti West irrigation demands. Water rights would have to be purchased.

It may also be possible to use return flows from NIIP irrigation, but quantity and quality of this supply are presently unknown. Again, water rights must be purchased.

A direct diversion from the San Juan River would be an alternative supply for irrigation. This alternative would require a pipeline of substantial length (roughly 31 miles as the crow flies); an easement would again be required. Quality of the water should be acceptable. Because San Juan River water is fully allocated, however, direct diversion from the river is not possible unless water rights are purchased.

Subsurface water in the Morrison Formation has potential as a supply for irrigation. In order to utilize this potential supply, a well about 5,000 feet deep would have to be developed or the existing test well modified. The formation could yield amounts of about 500 gal/min. Water quality tests on two nearby wells in the formation show varying results. More study is needed to draw better conclusions on the quality of the formation's water. Water rights would probably present no problems. However, the New Mexico State Engineer has designated the San Juan Basin a "declared basin." This designation requires that a permit be obtained from his office to drill and develop any water supply well.

Additional studies to better define available water supply for use in revegetation.

1. Determination of accurate local flow values for use in impoundment feasibility studies.

2. Investigation of impoundment sites and the quality of water that would be stored.

3. Investigation of the Morrison formation as a supply source.

4. Investigation of water rights and cost of water.

5. Investigation of system costs.

Conclusions. If water rights problems can be overcome, the most viable alternatives for water supplies for irrigation (if applied) appear to be: (a) develop reservoir storage equal to about 1,500 acre-feet on a suitable nearby drainage, (b) obtain a supply of water from Navajo Reservoir through NIIP facilities during off-peak periods, or (c) combine forms of both the foregoing alternatives.

Effects of Mining on Area Hydrology

Probable hydrologic impacts from mining the Bisti EMRIA study site on the surface water system will be localized to the mine area and will have negligible effects on the San Juan River.

An increase in runoff could occur because construction of surface facilities will cause a slight increase in impermeable surfaces within the area. Surface flow may be induced if ground water seepage and surface runoff into the mine is allowed to be pumped into the surface channels. This mine discharge will probably be of poor quality water and should not be pumped into arroyos or other channels unless it can be established that this discharge will not contaminate the stream system downstream. Natural drainage patterns within the mine area will be destroyed with overburden removal. New erosional channels will develop on the restored

overburden. If reclamation efforts restore deeply incised channels or if erosional channels develop in the reclamation area, increased sediment yields to the main arroyos may result. Any constructed reclamation channels should be in the form of gently sloping swales.

The mining will probably progress from southwest to northeast in the Bisti area, thus the mine pit would be upstream from the reclamation area. Runoff from spoil piles could be held in any depression between the piles and reclamation areas. Appropriate soil conservation techniques, such as contour furrowing, applied to the reclamation area would increase infiltration rates, spread any runoff that occurs, and reduce surface flow velocities.

Quality of surface waters may be affected by overburden removal, mixing the overburden, and exposure of overburden materials that are highly susceptible to weathering. Soluble products of weathering would be carried downstream by runoff. Clays, shales, silts, and other fine materials brought to the surface may degrade the quality of surface water because of increased ion exchange of undesirable chemical constituents into the water and decrease downward leaching of soluble salts on the soil. Also, disturbed or rerouted surface flow patterns may bring surface flow in contact with materials more soluble than materials in the natural drainage system.

The removal and replacement of overburden material will break up any stratigraphic layering and mix the minerals of the different layers. Any weathered or soluble substances not carried away by runoff from the spoil piles will be reburied in the coal-stripped pits. A single water zone will eventually develop above the floor of the former coal zone, and its water quality may be similar in chemical composition to a mixture of waters from stratified zones that existed above and possibly within the coal before being mined, except that it may be more mineralized. Localized and anomolous ground water conditions may be destroyed including the better water-quality conditions in sandy alluvial deposits and arroyo streambeds. If infiltration rates are increased in the restored overburden, the greater recharge from precipitation and runoff may help dilute any saline ground water within the overburden. The mining may tend to create a more uniform, but not necessarily improved, subsurface water system in the replaced overburden throughout the mined area. If the coal strata act as aquifers, these aquifers, of course, would be destroyed. If the coal strata act as aquitards, recharge from the surface will either move into an unsaturated zone in the Pictured Cliffs Formation; or, if an artesian head exists in the Pictured Cliffs Formation, the water from this formation will move upward into the altered overburden and mix with surface recharge. In either situation, the resulting quality is expected to be poor because of the exceptionally poor quality of water in the Pictured Cliffs Formation. This formation will probably be one of the sources of any poor quality ground water seeping into the coal pits. Another source of seepage will be the coal seam. Mine

seepage will create a disposal problem; however, if the Bisti study site is mined large volumes of this seepage are not expected because of the poor yielding characteristics of these formations.

Hydrologic Monitoring and Study Needs

For the Bisti EMRIA reclamation study site the following hydrologic monitoring program has been established:

(1) A surface-water gaging station was installed with an automatic pump sampler at the De-Na-Zin Wash at the road crossing downstream from the study site.

(2) Three crest stage gage stations on arroyos inflowing to or within the study site were installed. The stations are also equipped with sets of single-stage samplers.

(3) Three water observation wells for water-quality and water level have been drilled and completed in the Pictured Cliffs Formation, the water-bearing unit immediately below the coal.

(4) A network of 12 nonrecording rain gages has been placed on different parts of the De-Na-Zin Wash watershed.

(5) Four coal exploratory holes on the study site have been converted to water observation wells. Two are in the overburden and two are in the coal. The wells will be tested for water-bearing characteristics and sampled for water quality analyses.

Also, surface-water gages and water quality stations are in operation on Hunter Wash and Hunter Tributary near Bisti. Two local existing wells in the Cliffhouse Formation and in the Point Lookout Sandstone have been sampled in addition to the three wells developed for this project.

It is recommended that the above monitoring program be maintained before, during, and after mining. At least 5 years of records should be collected if the study site will not be mined in the immediate future. If the site is mined, it also will be necessary to monitor diversions, mine seepage, waste ponds, supply reservoirs, and the ground water table in the reclaimed area. Postmining monitoring should continue for at least 5 years after final rehabilitation efforts, with periodic reconnaissance thereafter.

Additional studies suggested to better define and monitor the water resource of the area are:

(1) Investigate the Morrison Formation in detail as a water supply source to meet reclamation needs.

(2) Further analyze channel geometry and discharge to obtain accurate peak and mean discharge values and other flow characteristics for ungaged arroyos.

(3) Make more accurate determination of areal variations of potentially damaging soluble inorganic and organic constituents in the overburden materials.

(4) Study the overburden and the coal strata for water-bearing characteristics and water quality.

(5) Study spoil piles for water-soluble substances and weathering into water-soluble substances.

(6) Determine aquifer characteristics of the Pictured Cliffs Sandstone.

(7) Install a meteorological station for continuous monitoring of precipitation, temperature, solar radiation, and wind. The data would be used to develop rainfall-runoff relationships for this and similar watersheds.

CHAPTER III

OBJECTIVE OF RECLAMATION - PLANNED LAND USES FOLLOWING RECLAMATION

Legal Requirements of Mine-Land Reclamation

If the Bisti West study site is leased for coal mining, because it is Federal land, the operator of the mine must comply with Federal regulations. Furthermore, because the operator will not be an instrumentality or agent of the Federal government, he must comply with State regulations.

Federal

The major Federal coal mining operating regulations were published in the Federal Register, Vol. 41, No. 96, May 17, 1976 (Part II, pages 20253-20273). Selected passages of the regulations are presented below, some in modified form. Other pertinent Federal regulations were published in the Federal Register in Vol 41, No. 90, May 7, 1976, (pages 18845-18848) and in Vol. 41, No. 105, May 28, 1976 (pages 21779-21781).

TITLE 43--PUBLIC LANDS, INTERIOR

CHAPTER II--BUREAU OF LAND MANAGEMENT, DEPARTMENT OF THE INTERIOR

PART 3040--ENVIRONMENT AND SAFETY

SUBPART 3041--SURFACE MANAGEMENT

FEDERAL COAL RESOURCES

Section 3041.0-1 - Purpose

(a) The purpose of this subpart is to establish rules and regulations to be followed in the management of the federally owned coal estate consistent with the policies, goals, and objectives established by the acts cited in section 3041.0-3 of this subpart, regardless of surface ownership, to assure effective and reasonable regulation of surface coal mining operations in accordance with the requirements hereof, as an appropriate and necessary means to minimize so far as practicable the adverse social, economic, and environmental effects of such operations.

(b) It is the policy of the Department to encourage the development of federally owned coal, where such development is authorized, through a program that will

provide for the protection, orderly development, and conservation of Federal mineral and nonmineral resources in a manner that will avoid, minimize, or correct adverse impacts on society and the environment resulting from coal development, without undue duplication or administrative delay by Federal officers. It is also the policy of the Department to issue leases, permits, and licenses for coal only where reclamation of the affected lands to the standards set forth herein is attainable and assured and a reclamation program will be undertaken as contemporaneously as practicable with operations.

Section 3041.1-2 - Preliminary data

(a) Any application for coal lease, permit, or license filed pursuant to the regulations in this chapter shall contain preliminary data (in lieu requirements also described).

(b) Such preliminary data shall include (1) maps of the topography of the land applied for; its physical features, roads, and utilities; and proposed exploration and mining operations and (2) a narrative statement covering proposed exploration operations and mining method; existing land use; known geologic, visual, cultural, or archeological features; known habitat of fish and wildlife that may be affected by the proposed operations; and proposed measures to prevent environmental damage and public hazard and to reclaim the surface.

Section 3041.2-2 - Obligations and Standards of Performance

(a) Any operator who accepts a coal base, permit, or license shall comply with, and be bound by, the general obligations and standards of performance set forth in this section and such additional and more stringent specific requirements as may be contained in the terms and conditions of such lease, permit, or license.

(d) The operator shall take visual resources into account in the planning, design, location, and construction of facilities and shall take action to minimize, control, or prevent damage to the recreational, cultural, scientific, historical, and known or suspected archeological and paleontological values of the land.

(f)(1) The operator shall reclaim affected lands pursuant to his approved plan, as contemporaneously as practicable with operations, to a condition capable of supporting all

practicable uses which such lands were capable of supporting immediately prior to any exploration or mining, or equal or better uses that have been approved in accordance with this subpart.

(2) The operator shall replace overburden and waste materials in the mined area by backfilling, grading, or other means, so as to cover all toxic materials and eliminate high walls and spoil piles and restore the approximate original contour. The operator shall use all available overburden or spoil material to obtain the lowest practicable grade, which shall in any event be less than the angle of repose. Excess overburden or other spoil material shall be fully reclaimed.

(3) The operator shall stabilize and protect all surface areas, including spoil piles, affected by the coal mining and reclamation operation, to effectively control slides, erosion, subsidence, and attendant air and water pollution.

(4) The operator shall remove topsoil separately, for replacement on the backfill area, and if not so utilized immediately, segregate it in a separate pile from other spoil. When topsoil is not to be replaced on a backfill area within a time short enough to avoid deterioration, the operator shall establish and maintain an approved quick growing vegetative cover or employ other approved measures so that the topsoil is protected from wind and water erosion and establishment of noxious plant species, and is in a condition for sustaining vegetation when used during reclamation. If topsoil is of insufficient quantity or of poor quality for sustaining vegetation, and if other excavated materials can be shown to be more suitable for revegetation, then the operator may be authorized in the approved plan to remove, segregate, protect, and utilize in a like manner such other materials.

(5) The operator shall assure that water impoundments, water retention facilities, dams, or settling ponds have been set forth in an approved plan, and are properly implemented.

(7) The operator shall utilize the best practicable commercially available technology to minimize, control, or prevent disturbances of the prevailing quality, quantity, and flow of water in surface and ground water systems, and of the prevailing erosion and deposition conditions at the mine site and in affected offsite areas, both during and after coal mining operations and reclamation.

(8) The operator shall properly treat or dispose of all rubbish and noxious substances and all waste resulting from the mining and preparation of coal in a manner designed to minimize, control, or prevent air and water pollution and the hazards of ignition and combustion.

(11) The operator shall design to applicable standards, construct, maintain, and, when no longer necessary and unless otherwise authorized in an approved plan, remove all roads, pipelines, powerlines, and similar utility access facilities and associated bridges, culverts, and ditches, into and across the site of operations, in a manner that will minimize, control, or prevent erosion and siltation, fugitive dust, pollution of water, damage to fish or wildlife or their habitat and public or private property.

(13)(i) The operator shall, except where other reclamation, based upon postmining land use and not requiring revegetation pursuant to the requirements of this section, is expressly provided for in an approved plan, establish on regraded areas and all other affected lands a diverse vegetative cover native to the area and capable of regeneration and plan succession at least equal in density and permanence to the natural vegetation, provided, however, that the Mining Supervisor, with the concurrence of the appropriate authorized officer may allow the use of approved mixtures of introduced or native species where preferable to achieve quick cover or assure successful revegetation. In approving such mixture, preference will be given to non-noxious species.

(ii) The operator's responsibility and liability under his performance bond for revegetation of each planting area shall extend until such time as the appropriate authorized officer, in consultation with the Mining Supervisor and the surface owner, if other than the United States, determines that successful revegetation in compliance with paragraph (i) of this subsection has occurred, provided, however, that this period shall extend for a minimum of 5 full years after the first planting, and for a total period of liability not to exceed 10 years from the original planting. (In certain instances this period of responsibility may not apply.)

(14)(ii) The operator shall regulate public access, vehicular traffic, and wildlife or livestock grazing in all areas of active operations, including lands

undergoing reclamation, in order to protect the public, wildlife, and livestock from hazards associated with such operations, and to protect revegetated areas from unplanned and uncontrolled grazing. For this purpose, the operator shall provide warning signs, fencing, flagmen, barricades, and other safety and protective measures as may be necessary.

Section 3041.5 - Completion of Operations and Abandonment

(a) Grading and backfilling. Upon completion of backfilling and grading as required by the approved plan and prior to replacing topsoil and revegetation, the operator shall submit a report thereon, in duplicate, to the Mining Supervisor and request inspection for approval. Whenever it is determined by such inspection that the backfilling and grading has met the requirements of the approved plan, the Mining Supervisor shall recommend to the appropriate authorized officer release of an appropriate amount of the compliance bond for the area satisfactorily backfilled and graded.

(c) Permanent abandonment. Methods of abandonment shall be approved in advance by the Mining Supervisor. Areas affected by access roads will be graded, drained, and revegetated in accordance with the approved Mining Plan and therein approved postmining land use prior to bond release. In the event that access or haul roads are intended to remain after abandonment of the operation, pursuant to section 3041.2-2(f)(11) of this subpart, they must be designed and constructed so as to be permanently stabilized using adequate drains, water barriers, and other practices.

TITLE 30--MINERAL RESOURCES

CHAPTER II--GEOLOGICAL SURVEY
DEPARTMENT OF THE INTERIOR

PART 211--COAL MINING OPERATING REGULATIONS

Section 211.75 - Applicability of State Law

(a) On the effective date of this part, and from time to time thereafter, the Secretary shall direct a prompt review of State laws and regulations in effect or adopted and due to come into effect, relating to reclamation of lands disturbed by surface mining of coal in each State in which Federal coal has been leased, permitted, or

licensed. If, after such review, the Secretary determines that the requirements of the laws and regulations of any such State afford general protection of environmental quality and values at least as stringent as would occur under exclusive application of this Part, he shall, by rulemaking, direct that the requirements of such State laws and regulations thereafter be applied as conditions upon the approval of any proposed exploration or mining plan, unless (i) the Secretary determines that such application of the requirements of such laws and regulations would unreasonably and substantially prevent the mining of Federal coal in such State, and (ii) the Secretary determines that it is in the overriding national interest that such coal be produced without such application of such requirements. In any such determination of overriding national interest, the Secretary will consult in advance of such determination with the Governor of the State involved.

State

Presented below, some in modified form, are selected passages from the regulations of the State of New Mexico, Coal Surface Mining Commission, (effective date--February 9, 1973) pursuant to New Mexico Coal Surface Mining Act, Chapter 68, Laws 1972.

Section 1 - Permit Application - Fees

A permit application accompanied by a written mining plan and signed by the operator shall be filed with the Director of the State Bureau of Mines and Mineral Resources along with the application and initial acreage fees required by Subparagraphs 1 and 2, Subsection A, Section 7, of the New Mexico Coal Surfacemining Act, Chapter 68, Laws 1972, hereinafter referred to as "the Act." Duplicates of the application and mining plan shall be filed with the Director of the Environmental Improvement Agency.

Section 2 - Mining Plan

The mining plan prepared by the operator for approval by the Commission shall set forth the following information:

F. Topographical maps showing drainage before, during and after mining.

G. Physiography before and after mining.

H. Present and future land use of study site and pertinent surrounding land.

I. Summary of climatological, topographical, soil, water, agricultural, wildlife, and other data pertinent to current and future land use of study site.

J. Water to be stored, diverted, or used and resulting pollutants.

K. Description and analyses of soils in area to be mined.

O. Existing depth of top soil in affected area.

P. Proposed efforts to remove and preserve top soil during mining.

R. Description of existing and postmining vegetation, planting times, and times for growth to maturity.

S. Detailed proposal and time schedule for revegetation.

V. Plans for disposal of waste materials.

Section 5 - Grading

A. Grading shall proceed as set out in the operator's mining plan. Grading shall be an integral part of the mining operation and shall be completed within a reasonable and prescribed time limit.

B. Grading shall be carried out so as to produce a greatly undulating topography or such other topography as is consistent with the proposed end use of the area stated in the approved mining plan.

C. Grading shall be done in such a manner as to control erosion and siltation of the affected area, surrounding property, and water courses.

D. Mining and grading shall not affect the drainage or streamflow in a manner that would impair or be detrimental to existing water rights or the availability of water for beneficial use in the State.

E. The operator shall grade the affected area, construct earth dams in final cuts of all operations, or take whatever measures are necessary to control water which is sufficiently toxic to be dangerous or harmful to or destructive of plant, animal, or human life; provided that a dam may be constructed in a final cut only if such construction

and impoundment would not be contrary to the water laws of this State.

F. Where waste material is to be deposited within the affected area, such deposits shall be in such designated areas and within such schedules as are set forth in the approved mining plan and shall be covered to a minimum depth as set forth in the approved mining plan. The operator shall commence grading and reclamation of that portion of the affected area to be used to deposit waste material immediately after cessation of the depositing of waste material.

G. Grading of access, haul or support roads, and final cuts as shown in the mining plan may be excepted or deferred, with the approval of the Commission. Final cuts whose grading is to be excepted or deferred, must be graded, to the extent necessary, upon the order of the Commission if the Commission determines that the ungraded final cut is (1) interfering with drainage or forming pools detrimentally affecting existing water rights or the availability of water for beneficial use in the State, or (2) leaving a condition which may cause a loss of coal resource by fire or excessive oxidation.

Section 6 - Revegetation

A. Revegetation shall proceed as set out in the operator's approved mining plan. Revegetation shall be an integral part of the mining operation, shall be carried out to the extent practicable in consultation with the local soil and water conservation district, and shall be completed within a reasonable and prescribed time limit.

B. The operator shall revegetate the affected area in the following manner for the appropriate end use stated in the operator's mining plan:

(1) Forest Planting - The type of trees to be planted shall be as set forth in the approved mining plan. In passing upon the type of trees to be planted, the Commission shall consider the character and nature of the soil, the altitude, the temperature, and the precipitation at the site. Planting methods and care of planting stock shall be governed by professionally accepted reforestation practices.

(2) Range - The vegetative species to be planted or seeded shall be as set forth in the approved mining plan. The character and nature of the soil, the natural rainfall and the intended capacity of the area for grazing by livestock following the stripmining activity shall be considered by the Commission in passing on the operator's selection.

(3) Agricultural or Horticultural Crops - Seeding plans and planting rates shall be as set forth in the approved mining plan.

(4) Special Projects - Affected areas to be developed for selected purposes such as recreational, residential, industrial, or other special uses shall have a reclamation program suitable for the specific use set forth in the approved mining plan.

C. The operator, with the consent of the Commission, may delay planting or seeding the affected area during any period in which the operator is conducting research on more productive methods of revegetation.

D. Revegetation of haulage roads shall not be required where the road has been adequately surfaced and the operator or owner of the property has demonstrated to the satisfaction of the Commission that the roads will be required for a substantial use after strip mining operations have terminated.

E. Upon application by the operator concerning any portion of affected area, the Commission shall investigate whether the operator has completed the reclamation set forth in the approved mining plan or if, considering the natural condition and vegetation prior to strip mining, technical and economic practicability, future productivity for the end use stated in the approved mining plan, esthetic appearance and peculiar condition of the geographic area in which the strip mine is located, further revegetation efforts are justified. If the Commission shall determine that the reclamation set forth in the mining plan has been completed or that further revegetation efforts are not justified, it shall certify such decision to the operator and he shall thereupon be released from further reclamation duties with respect to the portion of affected area concerned, including any bond relating thereto.

Local

There are no local regulations concerning coal surface mining.

Bureau of Land Management District Management Framework Plan

According to the plan, land use of the Bisti West study site following mining would be grazing of livestock and protection of watershed and wildlife habitat. The plan may be inspected at the Bureau of Land Management District Office, 3550 Pan American Freeway, NE., Albuquerque, New Mexico 87107 and at the Farmington Resource Area Headquarters, 900 La Plata Highway, Farmington, New Mexico 87401.

CHAPTER IV

RECOMMENDATIONS FOR RECLAMATION

Four alternatives for postmining reclamation were considered and are discussed below: no mining, natural recovery, total revegetation, and partial revegetation. Partial revegetation is the alternative jointly selected by BLM, GS, and BR as being the most reasonable. This alternative is discussed in detail below.

No Mining

Responsible agencies could decide that the Bisti West study site should not be mined because the environmental resources lost by mining would outweigh the value of the energy resources gained. It must be assumed, however, that any mining plan approved for the site would be a reasonable one. Under such a plan, significant air and water pollution would be prevented; technology exists to accomplish this.

Also under such a plan, reasonable efforts would be made to prevent loss of existing land forms, esthetics, vegetation, and wildlife. At Bisti West such efforts may not be successful, however, because of the difficult reclamation problems involved. Therefore, substantial loss of these resources could occur. But even in this event, for the Bisti West study site, the value of environmental resources lost by mining would be far less than the value of energy resources gained. For this reason, this alternative is not deemed realistic and is not considered further in this report.

Natural Recovery

Under this alternative, materials suitable for planting media would not be separated from unsuitable materials. Spoil piles would simply be shoved back into the pits after the coal has been removed, minimally graded, and left for natural revegetation. Natural revegetation would be a slow process, at best, in this arid region, although the time required for it has not been determined. Indeed, these spoil piles, consisting mostly of materials unsuitable for revegetation, might never become revegetated. Through wind and water erosion, unvegetated spoil piles could contaminate adjacent unmined land areas and downstream water supplies. Local wildlife and domestic stock would be deprived of vegetation for cover and grazing until vegetation is reestablished. Whatever esthetic value the study site now has would probably be lost because the existing land forms would be destroyed and the new ones would be haphazard and subject to wind and water erosion until revegetation occurs. For these reasons, this alternative does not appear desirable and is not given further consideration in this report.

Total Revegetation

Revegetation of the entire surface-mined area would be very difficult because this would require that the entire site have a covering layer of suitable planting media of adequate thickness. Because there are insufficient planting media within the study site, the additional planting media would have to be borrowed from outside the study site. This would require another land classification survey to properly identify suitable soils. If suitable planting media were found and transported to Bisti West, a revegetation program would have to be conducted at the borrow site.

Therefore, if the Bisti West study site is entirely revegetated, the revegetation program would be similar to that for partial revegetation, except that it would be considerably more extensive and costly, and the two major limiting factors in the area of the study site--available planting media and irrigation water--would assume greater importance.

In light of the difficulty of only partially revegetating the study site, total revegetation of the site is unrealistic. In addition, partial revegetation of the study site is consistent with the guidelines for this report (Agreement between BLM and BR, FY76 Work Order No. 10) which states, "For planning purposes the Bisti West site will be returned as near as possible to its natural condition." For these reasons, the alternative of total revegetation of the study site is not considered further in this report.

Partial Revegetation

Under this alternative, the entire site would be carefully graded, but only a portion of it would be revegetated to approximate the existing level of vegetative cover; grading and location of vegetation would not necessarily be the same as at present. The rest of the site would be reclaimed so as to minimize erosion and then allowed to naturally revegetate. The plans presented in detail below for implementing this alternative could be carried out with or without irrigation, as indicated below. Since the study site has only limited amounts of planting media, and since revegetation of arid areas--such as the Bisti West study site--is difficult, this alternative appears to be the most logical of those presented and is recommended accordingly.

Actions during the premining and mining periods

Selection of planting media. Existing suitable surface soils (classes 1, 2, and 3) appear to be the only source of planting media.

These soils have some organic matter content and adequate physical condition, are easier to physically handle, and probably already contain native seeds which would aid in vegetation establishment.

The soils usually occupy mesas, ridges, and elevated benches of the study site. Just before starting the mining operation, a detailed site inventory must be completed, however, to pinpoint the location of and to more carefully evaluate the planting media of the study site.

Laboratory analysis of bedrock overburden at the study site indicates that it is unsuitable as a planting media in its present condition (see table B-6). However, reclamation at the nearby Navajo Coal Mine indicates that revegetation of overburden material that includes bedrock may be possible. Therefore, further studies should be made of bedrock overburden at the Bisti West study site to determine if it is suitable as planting media.

A comprehensive test-plot program should be conducted at the study site before mining begins. The program should include use of bedrock overburden as a planting media; simulation of growing conditions and techniques appropriate to the study site; and use of commercial developments for erosion control and revegetation.

Handling and placement of soil and bedrock material

Stockpiling of soil or bedrock to be used on surface--Existing suitable surface soils should be stockpiled in a readily identifiable way during mining so that they can be properly placed on the surface during final forming of a reconstructed landform. Both residual clay and wind-blown sandy soil materials occur over the surface of the study area. It is essential that each of these soil materials be removed and stockpiled separately. During stockpiling the suitable planting media must be separated from the unsuitable, and contamination kept to a minimum. All stockpiles must be protected from erosion. Long axes of the stockpiles should approximate the prevailing wind direction to minimize wind erosion. Undue compaction of planting media should be avoided during handling.

Probable resulting soil profile--Since the source of suitable planting media is limited, the reconstructed soil profile will probably be somewhat shallow. Some of the vegetation at the study site is found on areas with less than 18 inches of soil material. There are also partially barren areas where sparse vegetation grows on very shallow eolian deposits, sometimes less than 12 inches thick. These examples of existing vegetation indicate that a large amount of planting media is not needed for plant growth.

Almost all the planting media will have coarse textures with variable hydraulic conductivity, but some of the planting media will have fine textures with limited permeability. The planting media should be spread in strata so that a foot or more of the finer textured soils are near the bottom (to impede infiltration of water); on top of that layer should be placed 12 to 16 inches of sandy material composed of particles of various sizes. The minimum depth of sandy material over fine-textured material should be about 8 inches.

Some sodic and saline soils will be included in the planting media but will be within the suitable category. Indeed, the sodic soils may be an asset in establishing and maintaining vegetation because sodic conditions impede moisture movement in soils, reducing the rapid permeability of the coarse textured soils. Some materials classed as 6 because of high sodicity could be used as a barrier and planting media distributed over this barrier. Moisture would accumulate in the media and be more readily available to vegetation.

Placement and isolation of toxic materials. A major factor to be considered during handling of overburden will be the proper disposition of toxic materials. Laboratory analysis and greenhouse tests of the overburden material sampled in 1975 are presently the only source of information on toxic materials at the study site. This information and field observations reveal that much of the soil and bedrock overburden at the Bisti West study site, while not toxic, is sodic or saline. The detailed inventory of the site may reveal toxic elements not disclosed in these first analyses.

All toxic materials at the site should be identified before stripping; stockpiled; isolated; protected to prevent contamination of water supplies and potential planting media; and placed after mining so as to preclude future exposure.

Grading. One objective of replacing overburden and reshaping topography should be the creation of final topography which will blend with the form of the adjoining undisturbed landscape and the reestablishment of a positive surface drainage pattern. Reshaping to blend may not always be desirable, however. It should be possible to reduce the steeper slopes, which are usually of relatively short reach. This reduction of slopes would lessen erosion hazard, increase the success potential of revegetation, and reduce operational problems.

Well planned grading will promote full use of local precipitation for establishing and maintaining vegetation. This could be accomplished by constructing a series of shallow depressions and diversion structures and by contour furrowing. If the landscape is arranged for natural

rainfall collection, plants may take advantage of the rainfall to increase their chances of survival after irrigation (if used) is discontinued.

Slopes should not be steeper than 3 to 1 and, wherever possible, should be 4 to 1 or 5 to 1. Final grading should assure that no flat areas are created which will pond water unless temporary ponding is a part of the precipitation collection plan or erosion control program. Thus, if sand is not available for planting media in some areas, it would be advisable to surface these areas with finer-textured materials graded so that the surface is almost flat. Runoff could be reduced by treating the surface with an Arcadia furrower so that all the water falling on a site is retained until it infiltrates the soil. Water would be stored at shallower depths than in sandy soils, and a higher proportion of this water would be evaporated instead of transpired. Xerophytic shrubs and, possibly, certain short grasses could survive under these conditions.

Drainageways should be provided with grades flat enough to prevent gullying and excessive channel erosion. Flow retarding structures may be desirable. Resulting stream channels should have slopes equal to or less than those occurring before mining. Contour furrowing or some other practice should be done to temporarily minimize runoff until a grass cover has been established.

Grading plans should provide for permanently conducting drainage from the badland escarpment across the reclaimed area or for permanently diverting the drainage around the area.

Topographic plans for the finished areas should maximize north and east facing slopes. South and west facing slopes are traditionally drier and hotter in this area, thus making them more difficult to revegetate.

Sculpturing (excessive manipulation or grading) of the plant media should be avoided. The test plot program should provide information on effective grading techniques. Placement of planting media should be avoided during windy seasons or periods.

It may be desirable to prevent mining on steep slopes and to keep the final high wall slope less than 45°.

<u>Preventing adverse effects on surface and ground waters</u>. */ Major arroyos traversing strippable coal areas such as the De-Na-Zin Wash may have to be excluded from the mining operation because of potential difficulty in controlling high peak discharges and because of adverse effects on area and downstream surface and shallow ground water supplies.

Dams, diversion structures, channels, etc., should be designed to handle the severe stormflows anticipated during mining and reclamation.

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*/ This subsection prepared by Geological Survey.

Retention reservoirs on arroyos upstream from mine areas are suggested, with diversion channels beginning at the reservoir dam to accommodate reservoir overflow. Upstream runoff should be diverted around mining operations to prevent accumulation of large pools of poor quality water in mine pits, potential flooding of mining operations, and erosion of areas being reclaimed.

Mine water removed from the mine or poor quality waste water should be pumped into impermeable off-channel ponds for complete evaporation. Any waste water which would contaminate downstream supplies should not be discharged into an arroyo. Salts that precipitate in the evaporation ponds could be harvested and buried in the mine pits.

Rehabilitation efforts should restore land surfaces to allow leaching of accumulated salts downward. Overburden with a high percentage of soluble substances or fine material should not be placed on the surface.

The potential for liquid waste injection into deep geologic formations which are considered poor water quality aquifers and not likely to be developed for a water supply should be investigated.

Waste storage reservoirs should be lined or somehow rendered impermeable to leakage. Spillage of liquids (which could contaminate water supplies), solids used for mining operations, or solids resulting from mining operations should be prevented.

The newly begun hydrologic monitoring program for managing the quantity and quality of ground and surface water supplies in and around the mining area should be maintained before, during, and after mining operations. Postmining monitoring of diversions, mine seepage, waste ponds, supply reservoirs, and ground waters in the reclaimed area should continue for at least 5 years with periodic reconnaissance thereafter.

Additional studies suggested in the hydrology section of Chapter II to better define and monitor the water resource of the area should be considered.

Postmining operations for satisfactory reclamation

Evaluation of surface material for revegetation. This subject was introduced above in "Actions during the premining and mining periods." The surface material used for a planting media would be predominantly coarse textured. Some mixing of classes may be desired in order to acquire a more suitable texture, although doing so may lower the overall quality. Also, combining of classes into layers to promote utilization

of irrigation or rainwater will be desirable. All planting media classed suitable will support sufficient vegetation for reclamation with proper management.

Although most bedrock materials do not appear suitable as planting media, this should be confirmed by the test-plot program and by reclamation at the nearby Navajo coal mine.

Selection of species for seeding.

Native species (first priority)--Some of the soils of this study site have low moisture storage capabilities, yet some vegetation grows at the study site. This indicates that revegetation may be accomplished with arid land plant species. Other species may require more water than prevailing climate patterns provide. If possible, seeds should be obtained from local growers in order to be more climatically adapted and capable of survival at the study site.

The area will probably continue to be used for grazing of domestic animals and wildlife following mining. For this reason, a variety of both herbaceous and woody species should be seeded following shaping of the land surface and placement of planting media. The native species most suitable for seeding include the following:

Grasses

Common name	Scientific name
Alkali sacaton	*Sporobolus airoides*
Galleta	*Hilaria jamesii*
Indian ricegrass	*Oryzopsis hymenoides*
Ring muhly	*Muhlenbergia torreyi*
Sand dropseed	*Sporobolus cryptandrus*
Sand hill (spiny) muhly	*Muhlenbergia pungens*

Shrubs and Trees

Broom snakeweed */	*Gutierrezia sarothrae*
Fourwing saltbush	*Atriplex canescens*
Mormontea	*Ephedra* sp.
Rubber rabbitbrush	*Chrysothamnus nauseosus*
Shadscale	*Atriplex confertifolia*
Greasewood */	*Sarcobatus vermiculatus*

*/ toxic

Site appropriate seed mixes and seeding rates should be determined by BLM. Seed availability may be questionable for some species. The test-plot program should provide information about successful species, mixes, and seeding rates.

Adapted introduced species (second priority)--Because of the climatic conditions of the areas, no introduced plant species are recommended for seeding. However, research by other agencies and mining companies and the test plot program may reveal additional suitable species for the study site.

Nutrient deficiencies-additives. Fertility analysis of the planting media was not performed. Replacement of suitable soils should allow existing plant growth of the study site to continue and use of fertilizer (N_1P_1K) and additives (H_2SO_4, Gyp., etc.) should enhance the growth. Tests are required to confirm the latter assumption and the fertility of other overburden materials. The test-plot program should provide information.

Irrigation. Because of the arid climate, postmining establishment of vegetation at the study site without irrigation will be difficult. Timing of seeding will be crucial and will have to occur when moisture from rain or snow is present; but precipitation at the study site is erratic. Moisture may not be present when most needed to support newly seeded areas. With no moisture or vegetation to hold the soil, wind erosion could carry it off and with it the seeds. The seeds could be planted again; but the soil, in very short supply at the study site, would be lost. The erratic precipitation patterns might produce too much moisture--a cloudburst (not uncommon at the study site) that could sluice off the valuable unprotected soil. If there is moisture at the right time and in the right amount, the seeds would germinate. Then, if the next rain is too hard, the seedlings will be carried off with the eroded soil; or if the rain is inadequate, the seedlings will wither and die. In either event, the topsoil would again be susceptible to the scouring wind.

If irrigation is practiced as recommended by some authorities, seeding would not be so subject to the study site's erratic rainfall patterns. Germination and young plant growth would be quickly established and securely supported. The chance of wind or water erosion would be considerably less. A denser plant population would become established. If some plants died when irrigation was removed, the denser population should increase the chances that some plants will survive. The shock of removal of irrigation would be lessened by its gradual withdrawal.

Some authorities hold that the shock of removing regular fertilization and irrigation will seriously weaken or kill new plants and that revegetation should accordingly be accomplished without irrigation. At the nearby Navajo coal mine irrigation is being used to grow vegetation on spoil material. This irrigation has not been practiced long enough, however, to prove its worth. The benefits of irrigation in revegetation of areas such as the study site may, therefore, be moot.

Although additional research is needed to resolve this controversy, the authors of this report believe that temporary irrigation has the best chance of producing quick, successful revegetation at the Bisti West study site. The test-plot program should confirm the effectiveness of irrigation.

Another question concerns economics. Assuming water supplies for irrigation are technically feasible, it should be determined whether it is economically feasible to irrigate at the study site. One approach to such a determination would be to compare the cost of irrigation for 2 years (see below) to the cost of 10 successive years of seeding (including the cost of erosion control). The latter alternative might be required in order to establish vegetation without irrigation because of the erratic rainfall patterns and other harsh climatic and soil conditions at the study site.

Use of irrigation does not affect the plans for revegetating the study site presented in this report. The only difference would be that revegetation under irrigation should occur sooner and more successfully. As indicated in Evaluation of Available Water Supply for Use in Irrigation, Chapter II, if irrigation is chosen plants would be irrigated for their entire first year, receiving 15 inches of water. The following year they would receive one spot irrigation of about 2 inches during the growing season to wean them from irrigation.

Alternative irrigation systems would be "solid set" (best); "hand move" (next best); and "side roll" or "center pivot" (next best).

Most planting media are coarse textured with a low available water holding capacity of .75 to 1.75 inches of water per foot of media. However, placing finer textured soils or weathered bedrock (both having limited permeability) under the coarse-textured planting media will increase the amount of water the latter can hold to about 2.2 inches per foot of media. With a recommended average depth for the coarse planting media of about 14 inches, the average amount of available water should be about 2.5 inches. Light and frequent irrigations (assuming irrigation occurs), keeping the surface few inches of planting media moist, should keep all of it moist and enable germination, young-plant growth, and maintenance of vegetation.

Mechanical manipulation of in-place planting media will be necessary only if nonsandy planting media are used.

In areas where drainageways collect water in sufficient quantities to cause erosion, water spreaders should be considered. Water spreaders are systems of dikes designed to divert floodwater from a gully onto adjacent rangeland. Because of the normal low rainfall in this area, it can be expected that water spreaders would come into play only during rains of short duration and high intensity and during periods of rapid snowmelt.

The test-plot program should provide information on the above techniques.

Seeding methods. Test plots and fertility tests should provide information about seeding methods. More than one seeding may be required especially if irrigation is not practiced. The time of year when seeding should take place will depend on the particular seed mix being planted. Reclamation should be scheduled so that seeding takes place soon after final grading in order to avoid surface erosion. The species to be planted at the study site will have optimum seeding depths. Selection of the manner of seeding (see below) should be based on these depths. Seed may be planted by drilling with either an approved disk or shoe-type grass drill; by an approved hydroseeder; or by mechanical or hand broadcasting. Drilling is the preferred method.

Drill seeding--Sowing the seed mixture with either an approved disk or shoe-type grass drill is acceptable. If this method is used, the drill shall be regulated to uniformly distribute the seed at the rate specified for the site. Where possible, drilling shall be done on the contour or parallel with the slopes being seeded. The drill shall be regulated so that the seed is properly placed in the soil and covered with soil to the specified depth. If fertilizer is to be applied during seeding, the drill could be equipped with an approved fertilizer attachment for distributing fertilizer at a specified rate simultaneously with the drilling of the seed.

Hydroseeding--Seeding with an approved hydroseeder will be acceptable provided wind velocities permit uniform distribution of seed and nitrogen fertilizer slurry on the areas to be seeded. In hydroseeding operations, the mixture of seed and the fertilizer specified shall be properly mixed with water to form a slurry. The slurry mixture shall be prepared immediately prior to application and shall be promptly applied on the areas to be seeded and fertilized. Slurry mixtures prepared more than 1 hour prior to application are not acceptable. The hydroseeder shall be designed to assure that seed and fertilizer are uniformly applied at the recommended rates per acre. The hydroseeder shall be equipped with a paddle-type agitator and recirculation pump that will continually stir and mix the slurry to prevent settling of solids in corners and at the bottom of the tank and to maintain a uniform mixture of seed, fertilizer, and water at all times during the entire seeding operation. Immediately after the slurry mixture is applied to the soil surface, the seed shall be properly covered with soil to the specified depth if the surface area permits.

Mechanical broadcasting--A mechanical broadcaster of either the centrifugal type or pull type similar to fertilizer spreaders are acceptable. Any equipment of this type used for broadcast seeding shall be designed and regulated to assure that the proper seeding rate per acre is uniformly applied on areas to be seeded. When this method is used, seed and fertilizer may not be applied in the same mixture simultaneously; each shall be broadcast separately.

Hand broadcasting--Hand broadcasting may be performed on small, inaccessible areas. Seed application may be performed by using an approved hand broadcaster or by broadcasting the seed by hand from a sack or other suitable container. Whichever means is used, the seed shall be uniformly applied at the specified rate. When using this method, the seed and fertilizer shall be broadcast separately. Hand broadcasting is the preferred method for areas where drill seeding is impractical.

Additional planting procedures--Monocultures should be avoided in grass stand selection. A good mix of adapted species which are drought resistant and have good sod-forming characteristics should be selected. When a range mixture is used, determination of the recommended seeding rates should include the results of the test plots. Some seeds may be planted by mixing them with mulch (see below). The BLM's Farmington office can provide references to assist in choosing seeding methods.

Fertilizer applications. Fertility tests and the test-plot program should provide applicable information. If required, fertilization during seeding may be done as indicated above. Later in the growing season or in subsequent growing seasons, additional light applications of fertilizer may be desirable. Timing and rate of fertilizer application should be determined by the local manager, since it will have to be based on local observation and experience.

Surface soil protection. Selected mulch material shall be applied at the recommended rate immediately after planting and fertilization, and shall be anchored as appropriate. Following the mulching operation, wind barriers (snow fences) may be installed.

After seeding is completed, mulching is used to stabilize critical areas and enable plants to become established quickly in the surface material. Mulching nearly always shortens the time required to establish a suitable plant cover by reducing evaporation, moderating soil temperatures to promote germination and seedling growth, preventing crust, and controlling wind and water erosion. Any substance spread, formed, or left on the surface material may act as a mulch. There is a large variety of available mulching materials, including: straw, native hay, hay and other crop residues, sawdust, woodchips, wood fiber, bark, manure, brush, jute or burlap, uniform-sized coarse sand, gravel, mulch stones, peat, paper, leaves, plastic film bits, bottom ash, and various organic and inorganic liquids. In addition, commercial products and systems for protection of surface soils are available and should be considered.

Gravel or crushed rock can also be selected from overburden material and used successfully as a surface mulching material. There are large piles of scoria near Tanner Lake that would make excellent mulch material. These types of mulches have advantages over most other mulches because they are permanent if the individual pieces are no smaller than one-eighth inch in diameter. If the gravel or crushed stone pieces are no

smaller than this in size, the mulch cover will withstand a surface wind velocity of 85 mi/h. To control wind erosion the pieces must almost cover the soil surface (not less than 95 percent). The finer the gravel or crushed rock the less material is required to cover the ground surface.

Before a mulch is selected, systematic evaluation of the advantages and disadvantages of each type should be made considering factors such as transportation problems, application problems, resistance to erosive forces, insulating and evaporation retarding capacity, etc.

Protection of the surface soils from sustained high winds is essential. One method that has been successfully used to reduce surface erosion, as well as prevent injury to tender growing seedlings being established on a site, is to use wooden slat snow fencing material 5 to 6 feet in height. These fences should be installed perpendicular to the prevailing winds during the winter and spring seasons and should be located about 100 yards apart or closer if needed. The snow fence can be constructed with steel fence posts that can be driven into the soil or with wood posts that are hand set. Because of their cost and possible interference with irrigation activities, it may be desirable to limit placement of snow fences to only those areas which develop wind erosion problems after the 2-year irrigation period.

The test-plot program should provide information on fencing and mulching techniques. The BLM's Farmington office can provide references to assist in choosing mulching techniques.

Management

Grazing management is a necessity during revegetation. The new seedlings must be protected from grazing for at least three growing seasons; on the harsher sites, four or more growing seasons may be necessary. The young seedlings should not be grazed until they are firmly rooted. Adequate fencing will be required to prevent grazing by livestock during the establishment period.

Undesirable weeds may present harmful competition to seeded perennial species during the first two or three seasons after planting. It may be desirable to control these weeds through the use of selected herbicides during at least the first year of development.

SELECTED REFERENCES

Climate

Blaney, Harry F., and Hanson, Eldon G., State Engineer Office, 1965, Consumptive Use and Water Requirements in New Mexico (Technical Report No. 32).

Maker, H. J., Keetch, C. W., and Anderson, J. U., New Mexico State University, Agricultural Experiment Station, June 1973, Soil Associations and Land Classification for Irrigation, San Juan County (Research Report 257).

National Oceanographic and Atmospheric Administration, various dates, Climatological Data, New Mexico.

State Engineer Office, 1956, Climatological Summary, New Mexico (Technical Reports Nos. 5 and 6).

State Engineer Office, 1976, New Mexico State Water Plan.

U.S. Bureau of Reclamation, Upper Colorado River Regional Office, July 1974, Draft Environmental Statement 74-77, Proposed El Paso Coal Gasification Project, New Mexico.

U.S. Department of Commerce, May 1961, Rainfall Frequency Atlas of the United States (Technical Paper No. 40).

Geology

Baltz, Elmer H., 1967, Stratigraphy and Regional Tectonic Implications of Part of Upper Cretaceous and Tertiary Rocks, East Central San Juan Basin, New Mexico: Geol. Survey Prof. Paper 552.

Dane, C. H., and Bachman, G. O., 1957, Preliminary Geologic Map of the Northeastern Part of New Mexico: U.S. Geol. Survey Misc. Geol. Inv. Map I-224.

Kelley, V. C., 1950, Regional Structure of the San Juan Basin: New Mexico Geol. Soc. Guidebook, 1st Field Conference, San Juan Basin, New Mexico and Colorado: p. 101-108.

Sears, Julian D., 1934, Geology and Fuel Resources of the Southern Part of the San Juan Basin, New Mexico: Geol. Survey Bulletin 860-A, Part 1.

Shomaker, J. W., Beaumont, E. C., and Kottlowski, F. E., 1971, Strippable Low-Sulphur Coal Resources of the San Juan Basin in New Mexico and Colorado: Memoir No. 25, New Mexico Bureau of Mines and Mineral Resources.

Silver, Caswell, 1950, The Occurrences of Gas in the Cretaceous Rocks of the San Juan Basin, New Mexico and Colorado: New Mexico Geol. Soc. Guidebook, 1st Field Conference, San Juan Basin, New Mexico and Colorado: p. 109-123.

Silver, Caswell, 1951, Cretaceous Stratigraphy of the San Juan Basin, New Mexico Geol. Soc. Guidebook, 2nd Field Conference, South and West Sides of the San Juan Basin, New Mexico and Arizona: p. 104-118.

Coal Resources

American Society for Testing and Materials, 1974, Standard Specifications for Classification of Coals by Rank [ASTM Designation D388-66, (reapproved 1972)], in Gaseous Fuels; Coal and Coke; Atmospheric Analysis: Am. Soc. Testing Materials, pt. 26, p. 54-58.

Averitt, Paul, 1975, Coal Resources of the United States, January 1, 1974: U.S. Geol. Survey Bull. 1412, 131 p.

DeCarlo, J. A., Sheridan, E. T., and Murphy, Z. E., 1966, Sulfur Content of United States Coals: U.S. Bur. Mines Inf. Circ. 8312, 44 p.

Fieldner, A. C., Rice, W. E., and Moran, H. E., 1942, Typical Analyses of Coals of the United States: U.S. Bur. Mines Bull. 446, 45 p.

Francis, Wilfried, 1961, Coal, Its Formation and Composition: London, Edward Arnold (Publishers) Ltd., 806 p.

Lowry, H. H., ed., 1945, Chemistry of Coal Utilization, Volumes I and II: New York, John Wiley and Sons, Inc., 1,868 p.

Lowry, H. H., ed, 1963, Chemistry of Coal Utilization, Supplementary Volume: New York, John Wiley and Sons, Inc., 1,142 p.

Moore, E. S., 1940, Coal, Its Properties, Analysis, Classification, Geology, Extraction, Uses and Distribution: New York, John Wiley and Sons, Inc., 473 p.

Schopf, J. M., 1960, Field Description and Sampling of Coalbeds: U. S. Geol. Survey Bull. 1111-B, 70 p.

Schopf, J. M., 1966, Definitions of Peat and Coal and of Graphite that Terminates the Coal Series (Graphocite): Jour. Geology, V. 74, no. 5, pt. 1, p. 584-592.

Shomaker, John W., Beaumont, Edward C., and Kottlowski, Frank E., 1971, Strippable Low-sulfur Coal Resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, 189 p.

Snyder, N. H., 1950, Handbook on Coal Sampling: U. S. Bur. Mines Tech. Paper 133 (revised), 10 p.

Swanson, V. E., Huffman, Claude, Jr., and Hamilton, J. C., 1974, Composition and Trace-element Content of Coal, Northern Great Plains Area: Contribution to Mineral Resources Work Group, Northern Great Plains Resource Program.

Taylor, S. R., 1964, Abundance of Chemical Elements in the Continental Crust--a New Table: Geochim. et Cosmochim,. Acta, v. 28, No. 8, p. 1,273-1,285.

Tomkeieff, S. I., 1954, Coals and Bitumens and Related Fossil Carbonaceous Substances: London, Pergamon Press Ltd., 122 p.

U.S. Bureau of Mines, 1965, Bituminous Coal, in Mineral Facts and Problems, 1965, p. 119-147.

Soil and Bedrock

Cook, C. W., Hyde, R. M., and Sims, P. L., 1974, Revegetation Guidelines for Surface Mined Areas. CSU Range Sci. Dept. Science Series No. 16.

Diagnosis and Improvement of Saline and Alkali Soils, USDA Handbook No. 60, Richards, L. A., 1954.

New Mexico Range Plants--New Mexico State University Cooperative Extension Service, Circular 374, 1970.

New Mexico State University, Agricultural Experiment Station, Research Report 257, 1973.

Rai, D., Wierenga, P. J., and Gould, W. L., 1974. Chemical and Physical Properties of Core Samples from Coal Bearing Formation in San Juan County, New Mexico. New Mexico State Univ. Ag. Exp. Station Res. Report 287.

Rehabilitation of Disturbed Lands by Berg, W. A., 1975, Agronomy Dept. CSU.

Restoring Surface-Mined Lands--U.S. Department of Agriculture Miscellaneous Pub. No. 1082, 1968.

Soil Survey Manual, USDA Handbook No. 18, 1971.

Staff, Soil Survey, Soil Classification, A Comprehensive System, Seventh Approximation, with supplements: 1960 Soil Conservation Service, U.S. Department of Agriculture.

American Society for Testing and Materials, 1964, Procedures for testing soils: Am. Soc. for Testing and Materials, Philadelphia, Pa.: 540 p.

Baver, L. D., 1938, Soil permeability in relation to non-capillary porosity: Soil Sci. Soc. of Am. Proceedings, p. 52-56.

Low, Philip F., 1961, Physical chemistry of clay-water interaction: Advances in Agronomy, v. 13, p. 269-327.

McQueen, I. S., and Miller, R. F., 1968, Calibration and Evaluation of a Wide-range Gravimetric Method for Measuring Moisture Stress: Soil Sci., v. 106, p. 225-231.

McQueen, I. S., and Miller, R. F., 1972, Soil Moisture and Energy Relationships Associated with Riparian Vegetation near San Carlos, Arizona: U. S. Geol. Survey Prof. Paper 655E: 51 p.

McQueen, I. S., and Miller, R. F., 1974, Approximating Soil Moisture Characteristics from Limited Data: Emperical Evidence and Tentative Model: Water Resources Research, v. 10, p. 521-527.

Meinzer, O. E., 1923, The occurrence of ground water in the United States: Water-supply Paper 489, 321 p.

Miller, R. F., McQueen, I. S., Branson, F. A., Shown, L. M., and Buller, W. M., 1969, An Evaluation of Range Floodwater Spreaders: Jour. of Range Management, v. 22, p. 246-257.

Miller, R. F., and McQueen, I. S., 1972, Approximating Recurring Moisture Relationships in Desert Soils: Eco-Physiological Foundation of Ecosystems Productivity in Arid Zone: Publishing House NAUKA Leningrad USSR p. 119-122.

Miller, Reuben F., and Ratzlaff, K. W., 1965, Chemistry of soil profiles indicates recurring patterns and modes of moisture migration: Soil Sci. Soc. of Am. Proceedings, V. 29, p. 263-266.

Richards, L. A., and others, 1954, Diagnosis and Improvement of Saline and Alkali Soils: U.S. Dept. Agr. Handbook 60, 160 p.

Rolfe, B. N., R. F. Miller, and I. S. McQueen, 1960, Dispersion characteristics of Montmorillonite, Kaolinite, and Illite clays in waters of varying quality, and their control with phosphate dispersants: U.S. Geol. Survey Prof. Paper 334-G, p. 229-273.

Schofield, R. K., 1935, The pF of the Water in the Soil: Internat. Congress Soil Sci. 3rd Trans v. 2, p. 37-48.

Shown, L. M., Miller, R. F., and Branson, F. A, 1969, Sagebrush Conversion to Grassland as Affected by Precipitation, Soil, and Cultural Practices: Jour. of Range Management, v. 22, p. 303-311.

Shown, L. M. et al., 1964, Comparability of soil saturation percentage with soil moisture equivalent measured in a cooled, humidified centrifuge: Agron. Abstract, p. 50.

Stiven, G. A., and M. A. Khan, 1966, Saturation percentage as a measure of soil texture in the lower Indus Basin: Soil Sci. v. 17, p. 255-263.

U.S. Department of Agriculture, 1941, Climate and Man: Year Book of Agriculture, 1,248 p.

U.S. Department of Agriculture, 1951, Soil Survey Manual: U.S. Dept. Agric. Handbook 18, 503 p.

Sediment Yield

Branson, F. A., Miller, R. F., and McQueen, I. S., 1966, Contour Furrowing, Pitting, and Ripping on Rangelands of the Western United States: Jour. Range Management, v. 19, p. 182-190.

Frickel, D. G., Shown, L. M., Patton, P. C., 1975, An Evaluation of Hillslope and Channel Lrosion in the Piceance Basin, Colorado: Colorado Water Conserv. Board, Water Resources Circ. 30 (in review).

Pacific Southwest Inter-Agency Committee, 1968, Report on Factors Affecting Sediment Yield in the Pacific Southwest Area: Water Management Subcommittee, Sedimentation Task Force, 10 p., two tables.

Shown, L. M., 1970, Evaluation of a Method for Estimating Sediment Yield: U.S. Geol. Survey Prof. Paper 700-B, p. B245-B249.

Strahler, A. N., 1952, Dynamic Basis of Geomorphology: Geol. Soc. Am. Bull 63, p. 923-938.

Hydrology

Hedman, E. R., 1970, Mean Annual Runoff as Related to Channel Geometry of Selected Streams in California: U.S. Geol. Survey Water-Supply Paper 1999 E.

Moore, D. O., 1968, Estimating Mean Runoff in Ungaged Semiarid Areas: IAHS Bull., V. XIII, No. 1, p. 28-39.

Scott, A. G., 1971, Preliminary Flood-frequency Relations and Summary of Maximum Discharges in New Mexico - A Progress Report: U.S. Geol. Survey Open-file Report, 76 p.

U. S. Department of Agriculture - Salinity Laboratory Staff, Richards, L. A., ed., 1954, Diagnosis and Improvement of Saline and Alkali Soils: U. S. Dept. Agricultural Handbook No. 60, Washington, U.S. Govt. Printing Office, 160 p.

U. S. Geological Survey Annual Report, 1975, Water Resources Data for New Mexico: U.S. Geol. Survey, Water Resources Div., New Mexico District Office, Albuquerque, New Mexico.

APPENDIXES

A. EMRIA Program Reports

B. Soils

C. Moisture Relationships in Soils Associated with Vegetation Types

D. Geology

E. Coal Resources

F. Hydrology

APPENDIX A

EMRIA PROGRAM REPORTS

EMRIA Report Number	Reclamation Study Area
1-75	Otter Creek, Montana, near Ashland
2-75	Hanna Basin, Wyoming, near Hanna
3-75	Taylor Creek, Colorado, near Craig
4-75	Alton, Utah, near Kanab
5-76	Bisti West, New Mexico, near Bisti
6-76	Foidel Creek, Colorado, near Steamboat Springs
7-76	Red Rim, Wyoming, near Rawlins
8-76	Bear Creek, Montana, near Ashland
9-76	Horse Nose Butte, North Dakota, near Manning
10-77	Beulah Trench, North Dakota, near Beulah
11-77	Pumpkin Creek, Montana, near Ashland
12-77	Hanging Woman, Montana, near Decker
13-77	White Tail Butte, Wyoming, near Recluse
14-77	Potter Mountain, Wyoming, near Rock Springs
15-77	Henry Mountain, Utah, near Cainville
16-77	Emery, Utah, near Emery
17-77	Kimbeto, New Mexico, near Chaco Canyon
18-77	Fish Creek, Colorado, near Steamboat Springs

APPENDIX B

SOILS

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Taxonomic Classification of Soils

Soils are classified so that the significant soil characteristics can be remembered. Classification is an assemblage of knowledge about soils and their relationships to one another and to the whole environment. Classification facilitates the development of principles that help in the understanding of the behavior of soils and their response to manipulation. Through classification and then through use of soil maps, the knowledge of soils can be applied to specific tracts of land.

The narrow categories of classification allow the application of soil knowledge to the management of range, watershed, woodland, wildlife, mined-land reclamation, and other engineering works.

The classification system has six categories. Beginning with the broadest, the categories are order, suborder, great group, subgroup, family, and series. In this system the criteria used as a basis for classification are soil properties that are observable and measurable. The properties are chosen, however, so that soils of similar genesis, or mode of origin, are grouped. In table 8 the major soil series at the study site are placed in the classification system. For further information about the system see Soil Taxonomy, USDA-SCS Agricultural Handbook No. 436, 1975.

7-1654 (7-73)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET ____ OF ____
CHKD BY	DATE	FEATURE	
DETAILS			

TABLE B-1

SOIL MAPPING UNIT ACREAGES

UNIT	SECTION			
	6	7	8	17
7001 ACTIVE DUNES	0	30	20	0
7002 BADLANDS	338	38	76	254
7003 DOAK-SHIPROCK ASSOC.	55	0	0	0
7004 DOAK-SHIPROCK-SHEPPARD ASSOC.	46	40	78	6
7005 FLUVENTS-FREQUENTLY FLOODED	0	11	42	3
7006 HUERFANO CLAY	46	63	9	35
7007 MAYOQUEEN-SHEPPARD COMPLEX	0	0	49	21
7008 SHEPPARD FINE SAND	85	46	30	74
7009 SHEPPARD SOILS--HUMMOCKY	0	27	87	6
7010 STUMBLE-TURLEY-LATON ASSOC.	67	279	86	121
7011 UFFENS SILTY CLAY	3	66	83	0
TOTAL	640	600	560	520
INDIAN TRUST LAND	0	40	80	120
GRAND TOTAL	640	640	640	640

1

LOCATION: 2150'W, 675'S, NE Cor. Sec. 6
PARENT MATERIAL: Alluvium
REMARKS: Profile on mesa

0-48, sl. ca. Nod. from 24"-48"
48-72, sl. stl., some gravel
72-132, s. and gr. mixed, mod. loose
132-180, s. and gr. mixed, mod. loose

2

NO LAB DATA

LOCATION: 500'W, 50'S, NE Cor. Sec. 6
PARENT MATERIAL: Alluvium
REMARKS: Profile on mesa 300' from badland

0-24, v. fri.
24-42, v. fri., mod. sti.
42-90, v. fri., v. sl. ca. veins
90-144, v. fri., v. sl. ca. veins, mod. loose

3

LOCATION: 1900'E, 1850'S, NW Cor. Sec. 6
PARENT MATERIAL: Alluvium
REMARKS: Some small blowouts and active dunes

0-36, v. fri., not loose
36-66, v. fri.
66-84, v. fri., sl. ca. mott. and veins
84-144, loose

7

LOCATION: 2700'E, 1225'S, NW Cor. Sec 6
PARENT MATERIAL: Alluvium
REMARKS: Profile at core drilling site 1

0-12, v. fri.
12-34, v. fri.
34-48, v. fri., soft ca. Nod.
48-90, v. fri., some gr.
90-108, loose

8

LOCATION: 1950'E, 25'N, SW Cor. Sec. 6
PARENT MATERIAL: Alluvium
REMARKS: Profile in bare spot

0-6, sl. hard
6-36, v. fri., mod. stl.
36-76, v. tough, sl. salt streaks
76-96, v. fri., mod. salt streaks
96-120, mod. tough, mod. sti.

9

LOCATION: 1875'E, 400'N, SW Cor. Sec. 6
PARENT MATERIAL: Alluvium
REMARKS: Profile on narrow sandy ridge

0-12, loose
12-48, v. fri.
48-54, v. fri.
54-60, SS, v. hard

10

LOCATION: 2500'N, 2050'W, SE Cor. Sec. 6
PARENT MATERIAL: Local alluvium
REMARKS: Near badland, surf. v. shallow

0-12, v. fri., sl. sti.
12-24, SS, hard, could not auger below 24"

11

LOCATION: 350'W, 2100'S, NE Cor. Sec. 6
PARENT MATERIAL: Local alluvium
REMARKS: Located in bare spot near badland

0-12, v. fri, v. sti.
12-36, v. fri., v. sti.
36-52, v. fri.
52-60, SS, v. hard, could not auger below 60"

12

LOCATION: 400'W, 2400'S, NE Cor. Sec 6
PARENT MATERIAL: Alluvium and Eolian
REMARKS: Located on sandy area

0-12, loose
12-36, v. fri., not loose
36-60, v. fri.
60-82, loose, some gr.
82-102, SS, v. hard, could not auger below 102"

13

NO LAB DATA

LOCATION: 425'W, 2475'N, SE Cor. Sec. 6
PARENT MATERIAL: Alluvium and Eolian
REMARKS: Located on sandy area, few bare spots of cemented soil

0-12, v. fri. T.Z. 12-18
12-36, v. stl, mod hard, sl. ca. mott.
36-44, soft, v. sti.
44-72, v. fri., mod. stl.
72-90, SS, hard, could not auger below 90"

14

LOCATION: 750'W, 2200'S, NE Cor. Sec. 6
PARENT MATERIAL: Alluvium and Eolian
REMARKS: Located on sandy area near bad-land

0-12, loose
12-48, loose
48-84, v. fri.
84-120, loose

15

LOCATION: 650'W, 1925'N, SE Cor. Sec. 6
PARENT MATERIAL: Alluvium and Eolian
REMARKS: Located on sandy area

0-12, loose
12-48, v. fri.
48-64, v. fri.
64-72, soft
72-80, v. fri.
80-90, SS, hard, could not auger below 90"

16

LOCATION: 400'W, 1650'N, SE Cor. Sec. 6
PARENT MATERIAL: Alluvium
REMARKS: Located between drain and sandy area, hard and cemented

0-12, sl. hard, sl. salt streaks
12-30, v. tough, v. pls., sl. salt streaks
30-46, mod. cemented
46-58, v. pls. and v. sti., mod. salt streaks
58-84, mod. cemented
84-114, mod. cemented, SS at 114"

17

LOCATION: 2000'W, 1050'N, SE Cor. Sec 6
PARENT MATERIAL: Alluvium and Eolian
REMARKS: On sandy area

0-12, loose
12-36, loose
36-84, v. fri., not loose
84-138, v. fri., not loose
138-162, sl. raw, v. sti., SS at 162"

18

LOCATION: 1700'W, 1350'N, SE Cor. Sec 6
PARENT MATERIAL: Alluvium
REMARKS: Sl. low area, rock outcrops to E.

0-12, v. stl., mod. fri., T. Z. 12-18
18-42, sl. cemented
42-64, tough, sl. sti.
64-86, mod. cemented, thin zone of gravel at 62"
86-96, v. sti, SS at 96"

19

LOCATION: 1800'W, 1550'N, SE Cor. Sec. 6
PARENT MATERIAL: Alluvium and Eolian
REMARKS: Sl. low area, soil cracks on surf.

0-12, v. sl. stl., tough, T. Z. 12-18
12-38, v. sti., v. tough, sl. ca. Nod.
38-80, mod. cemented
80-102, loose, some small gravel
102-120, v. hard at 102", thin lens of SS at 108", SCL at 112"

20

LOCATION: 1700'W, 2150'N, SE Cor. Sec. 6
PARENT MATERIAL: Eolian and alluvium
REMARKS: Located on sandy area, some small blowouts

0-12, loose
12-48, v. fri.
48-84, v. fri.
84-120, v. fri.

21

LOCATION: 1925'E, 950'N, SW Cor. Sec. 6
PARENT MATERIAL: Alluvium over residual
REMARKS: Very shallow topsoil

0-12, v. sti., mod. pls., T. Z. 12-14
14+, SS, tough

22

LOCATION: 400'E, 400'N, SW Cor. Sec. 6
PARENT MATERIAL: Alluvium
REMARKS: Bare area, some gravel on surf.

0-12, v. sti.
12-24, mod. hard
24-36, Sh, hard

24

LOCATION: 2675'E, 1050'N, SW Cor. Sec. 6
PARENT MATERIAL: Eolian
REMARKS: Sandy area

0-12, loose
12-48, not as loose as above
48-96, loose
96-120, loose

25

LOCATION: 2500'E, 75'N, SW Cor. Sec. 6
PARENT MATERIAL: Alluvium
REMARKS: Profile at core drilling site 2

0-12, soft to sl. hard
12-24, soft to hard
24-66, sl. hard or compact at 54"
66-90, soft
90-120, sl. sti., mod. pls., sl. ca. nod.

26

NO LAB DATA

LOCATION: 1900'W, 300'N, SE Cor. Sec. 6
PARENT MATERIAL: Alluvium
REMARKS: Located on bare spot

0-12, v. compact
12-24, v. compact, sl. sti.
24-48, sl. compact
48-60, sl. compact
60-100, mod. compact
100-120, v. pls. and tough, sl. ca. Nod.

71

NO LAB DATA

LOCATION: 2700'W, 1950'S, NE Cor. Sec. 6
PARENT MATERIAL: Residual
REMARKS: Badland, bottom of drains have shallow weathered sh.

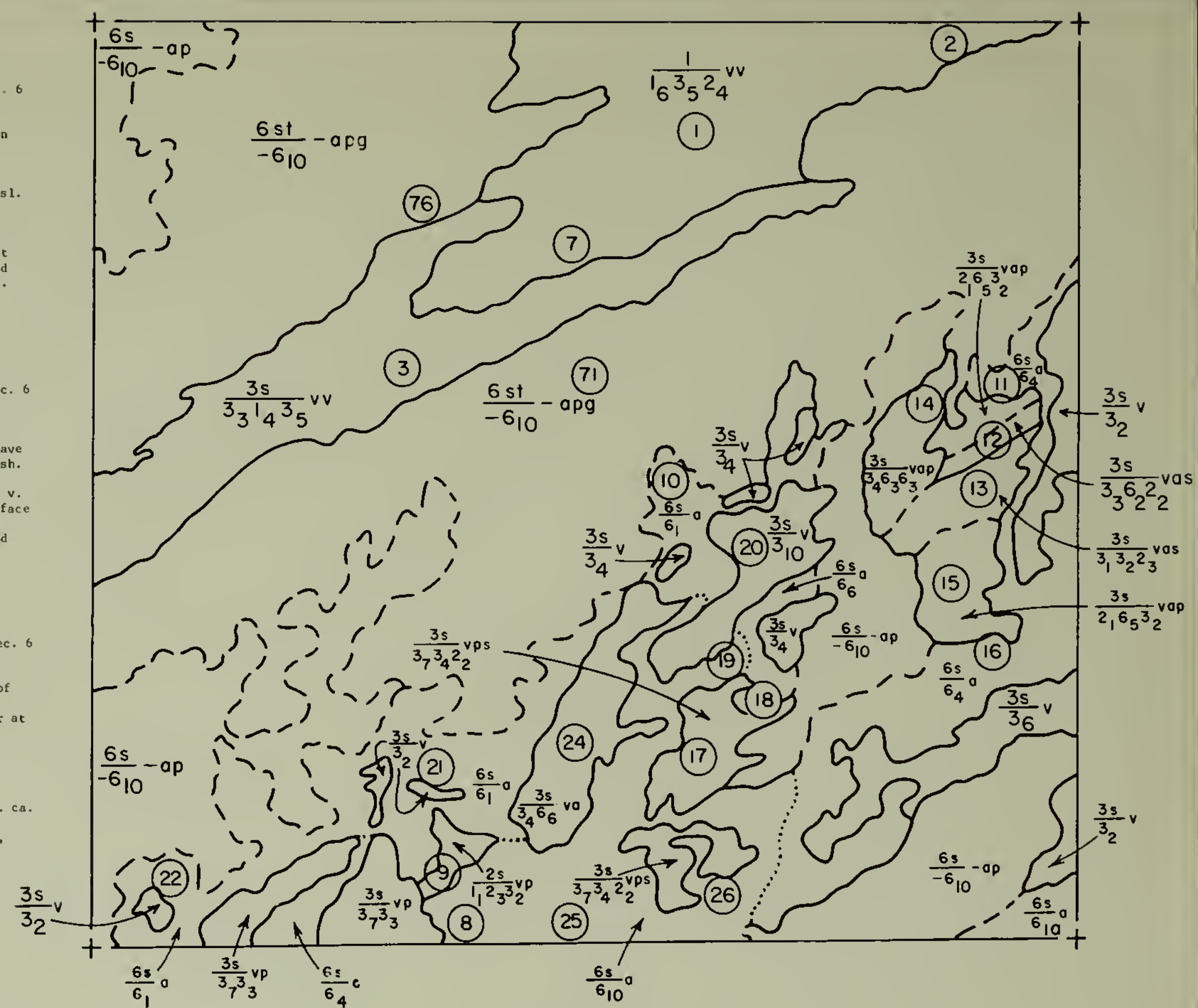
0-3, weathered sh., v. pls. and sti., surface is crusty
3+, sh, v. tough and hard

76

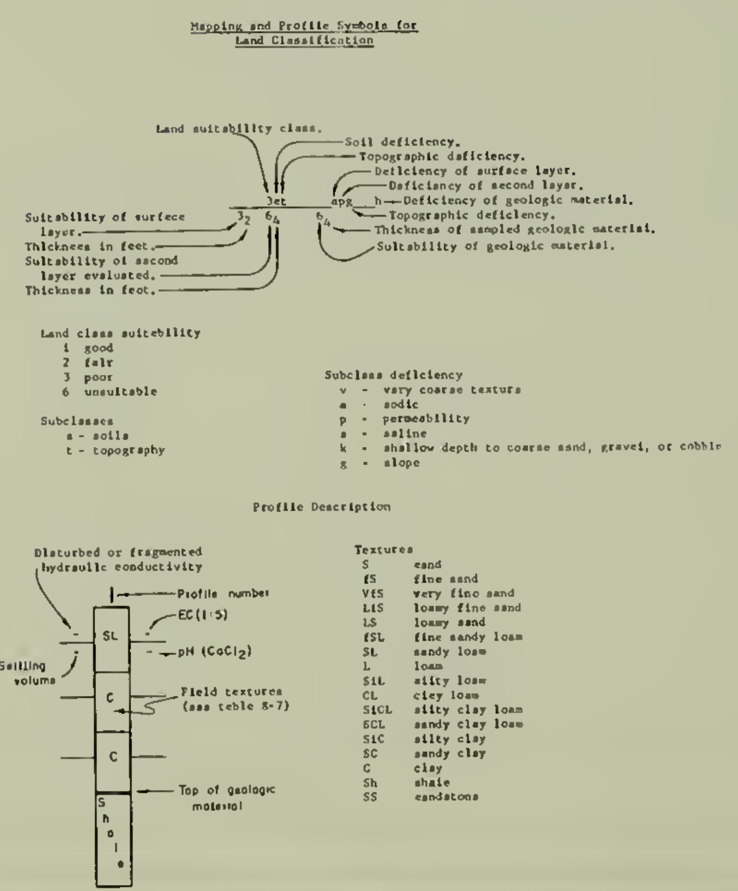
NO LAB DATA

LOCATION: 1000'S, 2000'E, NW Cor. Sec. 6
PARENT MATERIAL: Alluvium
REMARKS: N. edge of Alamo Mesa, soil material is deeper at this location

0-36, v. fri., not loose
36-66, v. fri.
66-84, v. fri., sl. ca. mott.
84-240, s. and gr., loose



SECTION 6



LEGEND

$\frac{2s}{2_3 1_2 6_5}$ vs LAND CLASS

(3) PROFILES

——— SEPARATES CLASSES
– – – – SEPARATES SUBCLASSES
·········· SEPARATES DEPTHS WITHIN SAME CLASS

LAND CLASS**	ACRES
1	56
2	2
3	131
TOTAL	189
6	451
ITL	0
GRAND TOTAL	640

** FOR COMPLETE ACREAGE OF EACH INDIVIDUAL LAND CLASSIFICATION SEE TABLE 8-2

* LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

BISTI WEST STUDY SITE

PROFILE DESCRIPTIONS* AND LAND CLASSIFICATION

EMRIA REPORT NO. 5-1976

FIGURE 8-1

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23

LOCATION: 800'E, 125'S, NW Cor. Sec. 7
PARENT MATERIAL: Eolian sand over alluvium
REMARKS: Sandy area, v. rough topog.

0-12, loose
12-48, not loose
48-84, loose
84-108, v. sl. compact
108-120, v. sti., sl. pls., mod. ca. mott.

27

LOCATION: 1375'E, 1000'S, NW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Located on bare area

0-12, soft
12-36, soft
36-50, soft
50-70, sl. hard, some small gravel
70-78, sl. hard, mod. sti.
78-94, coal
94+, shale

28 NO LAB DATA

LOCATION: 750'E, 1450'S, NW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Located near shallow drain

0-76, soft
76-120, coal
Only coal zone sampled

29

LOCATION: 650'E, 2000'S, NW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Located in bare area

0-12, soft
12-46, soft
46-64, soft
64-102, sl. compact
102+, SS

30

LOCATION: 200'E, 1925'N, SW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: This profile has more clay, many small scattered drains

0-12, soft
12-24, mod. fri., not tough
24-64, mod. fri., sl. ca. mott.
64-68, S., gr. and L. mixed
64-84, tough, mod. pls., sl. ca. mott.
84-96, mod. pls. tough
96+, SS

31

LOCATION: 2500'E, 1125'S, NW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Area sl. low

0-12, v. fri.
12-24, v. fri.
24-44, sl. sti., sl. ca. mott., some small gravel
44-120, v. fri., sl. sand increase at 54'

32

LOCATION: 2250'W, 450'S, NE Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Located between sandy area and SS outcrops

0-12, sl. sti., sl. hard, not tough
12-24, v. pls. hard to auger
24-60, soft, sl. pls.
60-84, v. pls. and sti., v. hard, sl. ca. mott.
84-102, sl. compact
102-120, weathered sh, mod. hard

33

LOCATION: 1875'W, 1300'E, NW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Almost barren area

0-12, sl. sti., soft, sl. pls.
12-48, sl. sti., soft
48-66, v. fri.
66-84, v. pls. and sti., lab. results missing
84+, sh

34

LOCATION: 450'E, 1150'N, SW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Sh and SS exposed all along drain to north

0-12, soft
12-36, soft
36-76, soft, sl. sti., thin zone of gr. at 60"
72-84, some coal and gravel, loose
84+, sh

35

LOCATION: 1925'E, 850'N, SW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Nearly level and barren

0-12, v. sti., mod. hard
12-24, soft, sl. sti.
24-48, soft
48-84, loose, some gr. mixed
84-120, loose

36

LOCATION: 2200'W, 950'N, SE Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Profile at core drilling site 4

0-12, sl. sti., mod. pls.
12-30, sl. sti., soft
30-60, soft
60-84, mod. sti., soft
84-120, soft

37

LOCATION: 1450'E, 1500'N, SW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Many areas of surf. gr.

0-12, tough and pls., st. salt cry., mod. sti.
12-30, tough and pls. sl. sti., sl. salt streaks
30-72, soft
72-96, soft

38

LOCATION: 1900'E, 1800'S, NW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Profile next to drain

0-12, mod. hard, sl. pls., mod. sti.
12-24, v. pls. and sti., v. tough and hard, sl. salt streaks
24-48, v. pls. and sti., sl. salt streaks
49-68, v. pls. and sti., mod. salt streaks
68-120, soft, thin zone of black S at 96" and 112", some gr. at 120"

39

LOCATION: 2250'W, 2100'S, NE Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Profile at core drilling site 3

0-13, mod. hard, mod. pls., some salt
12-36, sl. compact
36-42, some salt, no sample
42-72, soft
72-96, soft
96-120, mod. hard, v. sti.

40

LOCATION: 2100'E, 2500'N, SW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Bare area

0-12, v. fri. below 3" st. salt mott. 8"-12"
12-36, soft, no sample
36-60, v. pls and sti., sl. salt mott.
60-84, soft, no sample

41

LOCATION: 2125'W, 1600'S, NE Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Bare area, gr. on surf.

0-12, v. fri., some gr.
12-40, v. fri.
40-48, coal
48-108, soft and weathered sh.

42 NO LAB DATA

LOCATION: 1975'W, 1425'S, NE Cor. Sec. 7
PARENT MATERIAL: Alluvium and Eolian
REMARKS: The coal was the only sample taken

0-12, v. fri.
12-26, v. fri., sl. sti.
26-56, coal
56+, sh.

43

LOCATION: 200'W, 200'S, NE Cor. Sec. 7
PARENT MATERIAL: Eolian
REMARKS: Nearly flat area, v. sparse vegetation

0-12, soft, sl. sti.
12-22, soft, sl. sti.
22-42, v. hard, v. pls. and sti., sl. salt mott.
42-78, soft
78-120, soft, some fs at 114'

44

LOCATION: 300'W, 2400'N, SE Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Large, nearly level area, v. sparse vegetation

0-12, sl. hard, mod. pls. and sti.
12-44, soft, sl. sti.
44-72, sl. compact
72-94, loose
94-108, sl. compact, sl. salt mott.
108-120, s and gr., loose, no sample

45

LOCATION: 1000'W, 1700'S, NE Cor. Sec. 7
PARENT MATERIAL: Eolian and alluvium
REMARKS: Sandy area about 4' high

0-12, soft
12-42, soft, v. thin lens of C at 42"
42-66, soft, v. thin lens of C at 60"
66-90, sl. hard, st. salt mott. at 72"
90-120, sl. hard, st. salt mott. at 92"

46

LOCATION: 800'W, 450'S, NE Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Area sl. low or nearly level

Surface - soft, sl. pls. and sti.
0-12, v. tough, pls and sti.
12-30, sl. hard
30-54, tough, pls. and sti., sl. salt streaks
54-90, soft
90-108, sl. hard, sl. salt streaks
108-120, sl. hard, no sample

74 NO LAB DATA

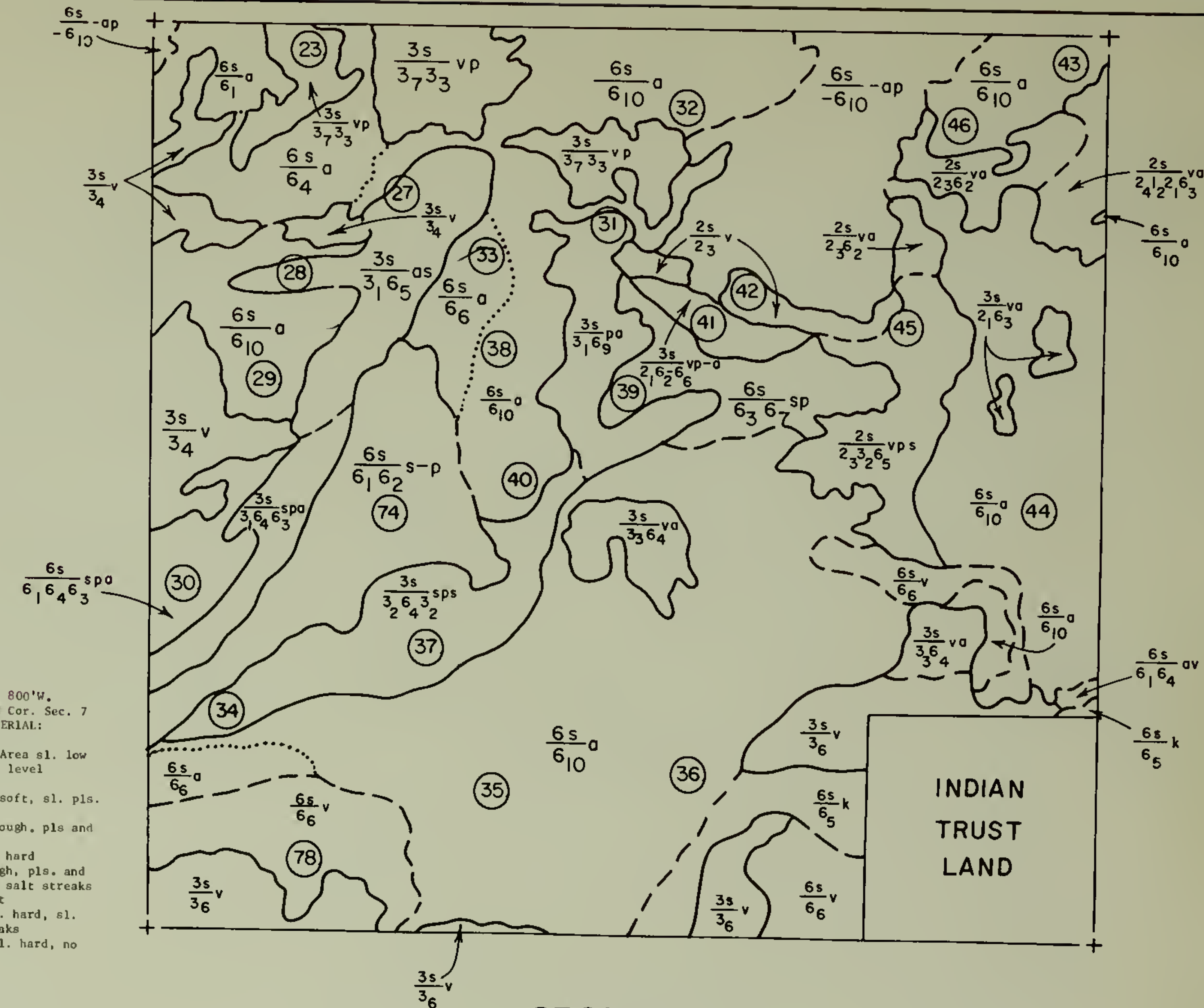
LOCATION: 1300'E, 2300'N, SW Cor. Sec. 7
PARENT MATERIAL: Alluvium
REMARKS: Shallow soil area over bedrock

0-12, mod. pls. and sti.
12+, sh. tough and hard

78 NO LAB DATA

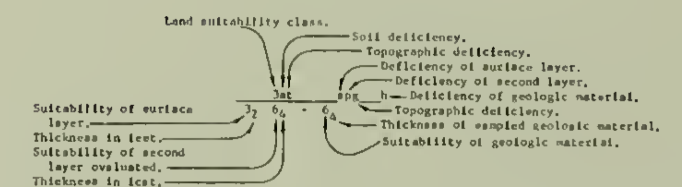
LOCATION: 500'N, 950'E, SW Cor. Sec. 7
PARENT MATERIAL: Eolian
REMARKS: Active dunes

0-60, loose, some coarse and v. coarse, a few scattered greasewood trees



SECTION 7

Mapping and Profile Symbols for Land Classification

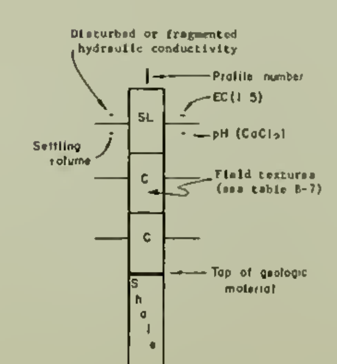


Land class suitability
1 good
2 fair
3 poor
6 unsuitable

Subclasses
s - soils
t - topography

Subclass deficiency
v - very coarse texture
a - sodic
p - permeability
e - saline
k - shallow depth to coarse sand, gravel, or cobble
g - slope

Profile Description



Textures
S sand
fS fine sand
VfS very fine sand
LfS loamy fine sand
LS loamy sand
fSL fine sandy loam
SL sandy loam
L loam
SiL silty loam
CL clay loam
SiCL silty clay loam
SCL sandy clay loam
SiC silty clay
SC sandy clay
C clay
Sh shale
SS sandstone

LEGEND

2s/2₃1₂6₅ vs LAND CLASS

(3) PROFILES

SEPARATES CLASSES
SEPARATES SUBCLASSES
SEPARATES DEPTHS WITHIN SAME CLASS

LAND CLASS**	ACRES
1	0
2	38
3	161
TOTAL	189
6	411
ITL	40
GRAND TOTAL	640

** FOR COMPLETE ACREAGE OF EACH INDIVIDUAL LAND CLASSIFICATION SEE TABLE 8-2

* LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

BISTI WEST STUDY SITE

PROFILE DESCRIPTIONS* AND LAND CLASSIFICATION

EMRIA REPORT NO. 5-1976

FIGURE 8-2

47

LOCATION: 375'E.
1850'S, NW Cor. Sec. 8
PARENT MATERIAL:
Alluvium
REMARKS: Area is covered with surf. gr.

Surface - sl. hard, sl. sti.
0-12, loose
12-30, loose, 30-36, no sample
36-78, soft, 78-90, coarse, no sample
90-120, sl. hard

48

LOCATION: 675'E,
1300'S, NW Cor. Sec. 8
PARENT MATERIAL: Eolian
REMARKS: Sandy area

0-12, loose
12-24, loose, no sample
24-48, soft
48-72, sl. hard
72-84, sand, no sample
84-102, sl. hard, sl. sti.
102-120, soft, mod. salt streaks

49

LOCATION: 1250'E,
800'S, NW Cor. Sec. 8
PARENT MATERIAL:
Alluvium
REMARKS: Sl. low area

0-12, sl. hard
12-60, sl. hard, thin zone of S at 36"
60-78, sl. hard, mod. salt mod.
78-120, sl. hard, sl. sti.

50

LOCATION: 2275'E,
125'S, NW Cor. Sec. 8
PARENT MATERIAL:
Alluvium
REMARKS: Profile at core drilling site 7

0-12, sl. hard, sl. sti.
12-36, sl. hard
36-60, sl. compact, some gr.
60+, sh. hard to auger

51

LOCATION: 610'W,
10'S, NE Cor. Sec. 8
PARENT MATERIAL: Eolian
REMARKS: Sandy area on mesa

0-12, loose
12-48, loose, sl. hard at 36"
48-72, mod. hard
72-120, sh. hard, weathered

52

LOCATION: 2100'W,
1775'S, NE Cor. Sec. 8
PARENT MATERIAL: Eolian
REMARKS: Low area on mesa

0-12, mod. hard and compact
12-30, mod hard
30-48, hard, tough, some gr. mixed
48-72, sh. hard, tough, sl. gr. zone at 66"
72+, sh. gr., hard and tough

53

LOCATION: 2500'W,
1400'S, NE Cor. Sec. 8
PARENT MATERIAL: Eolian
REMARKS: Sandy ridge

0-12, soft
12-48, soft
48-96, soft
96-120, loose

54

LOCATION: 1725'E,
2200'N, SW Cor. Sec. 8
PARENT MATERIAL:
Alluvium
REMARKS: Profile at core drilling site 6

0-12, hard, gyp zone at 6"
12-24, sh, hard and tough
24-36, SS, v. hard

55

NO LAB DATA

LOCATION: 575'E,
1850'N, SW Cor. Sec. 8
PARENT MATERIAL:
Alluvium
REMARKS: Only coal zone sampled

0-12, sh. hard
12-36, soft
36-72, v. hard., v. pls. and sti.
72-120, coal

62

LOCATION: 1550'W,
150'N, SE Cor. Sec. 8
PARENT MATERIAL:
Alluvium
REMARKS: Small bare area just south of Coal Creek

0-12, sl. hard, sl. sti.
12-60, sl. hard
60-80, sl. hard
80-120, soft, but not loose

64

LOCATION: 50'W,
250'N, SE Cor. Sec. 8
PARENT MATERIAL:
Alluvium
REMARKS: Nearly level area

0-6, v. sl. hard, mod. sti. and pls.
6-14, soft, sl. pls.
14-24, soft
24-48, soft
48-84, soft
84-120, mod. cem., some s. and gr. mixed

65

LOCATION: 1550'W,
575'N, SE Cor. Sec. 8
PARENT MATERIAL:
Alluvium
REMARKS: Bare area, scattered greasewood

0-12, sl. hard, mod. salt mott.
12-24, sl. hard, mod. sti.
24-60, sl. hard
60-90, sl. hard, sl. salt mott
90-120, not loose, some gr., v. thin lens of C at 96" and 114"

66

LOCATION: 275'W,
1000'N, SE Cor. Sec 8
PARENT MATERIAL:
Alluvium
REMARKS: Nearly level, large cracks

0-12, mod. hard, mod. pls and sti.
12-24, v. hard, v. pls. and sti., mod. salt mott.
24-48, soft, mod. pls. and sti.
48-66, v. hard, mod. pls., v. sti.
66-96, sl. hard, mod. pls., v. sti.
96-116, soft, mod. pls., v. sti.

67

LOCATION: 50'W,
475'N, SE Cor. Sec. 8
PARENT MATERIAL:
Alluvium
REMARKS: Nearly level area

0-12, v. hard, mod. pls. and sti.
12-42, sl. hard, mod. pls. and sti.
42-52, mixed T. Z., no sample
52-60, soft, sl. sti.

70

NO LAB DATA

LOCATION: 1550'W,
1850'S, NE Cor. Sec. 8
PARENT MATERIAL:
Eolian
REMARKS: Sandy area on mesa

0-3, loose
3-12, sl. hard
12-24, loose
24-38, loose
38-60, loose

72

NO LAB DATA

LOCATION: 1800'W,
1100'N, SE Cor. Sec. 8
PARENT MATERIAL:
Alluvium
REMARKS: Stream channel

0-60, S and gr., no free H_2O, some small lenses of fine textures, these are sti.

73

NO LAB DATA

LOCATION: 400'W,
2300'N, SE Cor. Sec. 8
PARENT MATERIAL: Eolian
REMARKS: Hummocky area, some crusty and bare spots

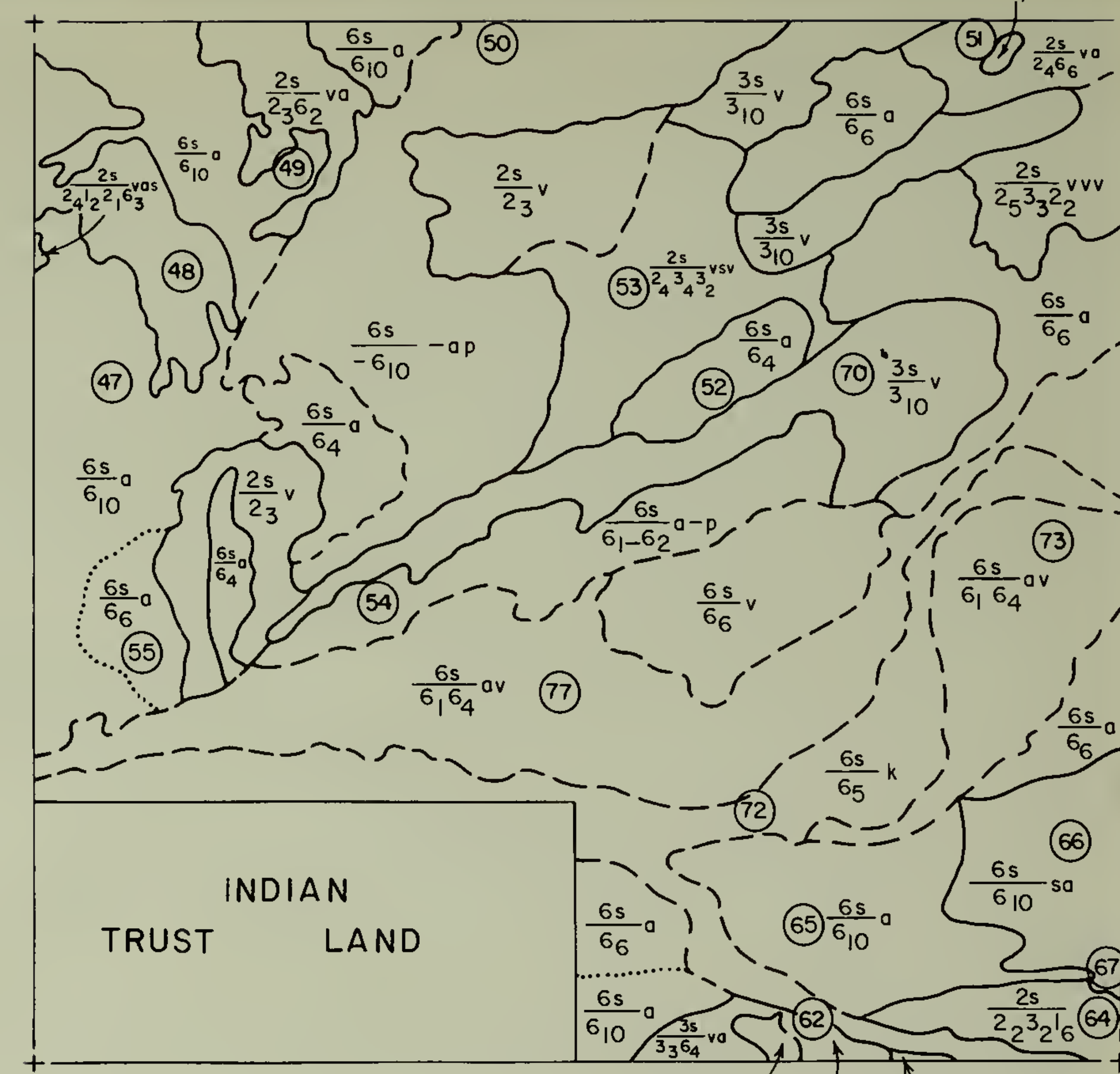
0-12, crusty surf., mod. sti., mod. cem.
12-48, loose, non-pls. and sti.
48-60, loose, non-pls. and sti.

77

NO LAB DATA

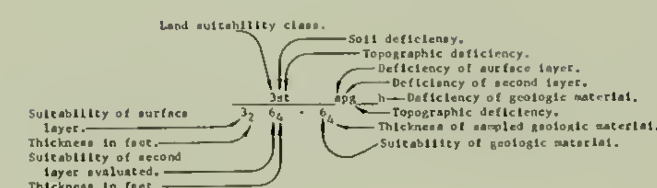
LOCATION: 2600'E,
1700'N, SW Cor. Sec. 8
PARENT MATERIAL: Eolian
REMARKS: Hummocky area, some rock outcrops

0-12, cem. mod. sti., surf. soils crusty
12-36, mod. loose
36+, sh.



SECTION 8

Mapping and Profile Symbols for Land Classification

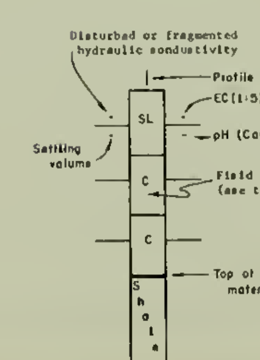


Land class suitability
1 good
2 fair
3 poor
6 unsuitable

Subclasses
s - soils
t - topography

Subclass deficiency
v - very coarse texture
a - sodic
p - permeability
s - saline
k - shallow depth to coarse sand, gravel, or cobble
g - slope

Profile Description



Textures
S sand
fS fine sand
VfS very fine sand
LfS loamy fine sand
LS loamy sand
fSL fine sandy loam
SL sandy loam
L loam
SiL silty loam
CL clay loam
SiCL silty clay loam
SCL sandy clay loam
SiC silty clay
SC sandy clay
C clay
Sh shale
SS sandstone

LEGEND

$\frac{2s}{2_3 1_2 6_5}$ vs LAND CLASS

(3) PROFILES

SEPARATES CLASSES
SEPARATES SUBCLASSES
SEPARATES DEPTHS WITHIN SAME CLASS

LAND CLASS**	ACRES
1	0
2	108
3	51
TOTAL	159
6	401
ITL	80
GRAND TOTAL	640

** FOR COMPLETE ACREAGE OF EACH INDIVIDUAL LAND CLASSIFICATION SEE TABLE B-2

* LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

BISTI WEST STUDY SITE

PROFILE DESCRIPTIONS* AND LAND CLASSIFICATION

EMRIA REPORT NO. 5-1976

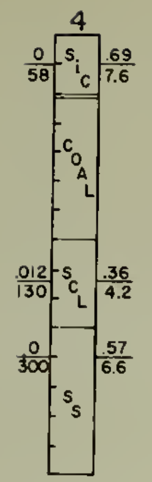
FIGURE B-3

7-
B

B

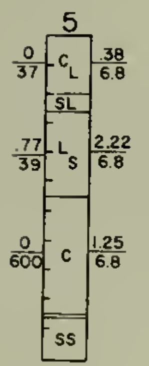
C

D



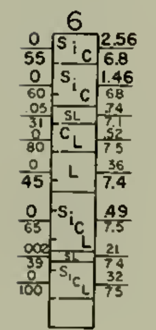
LOCATION: 1975'S, 675'E, NW Cor. Sec. 17
PARENT MATERIAL: Alluvium
REMARKS: Large cracks, old lakebed

0-24, v. tough, pls. and sti., T.Z. 18-24
24-84, weathered coal
84-120, mixed layers and zones of diff. textures
120-144, sl. sti., v. hard at 144"



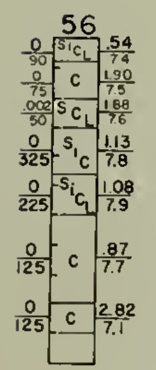
LOCATION: 875'E, 175'S, NW Cor. Sec. 17
PARENT MATERIAL: Alluvium
REMARKS: Almost barren area

0-24, soft and fluffy, v. stl.
24-32, not sampled
32-66, v. fri., v. stl., sl. yell. streaks
66-114, hard to auger, some s., v. hard at 114". SS at 114"



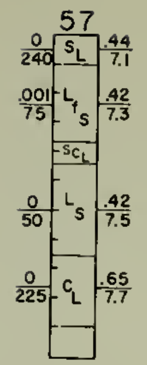
LOCATION: 1500'W, 625'S, NE Cor. Sec. 17
PARENT MATERIAL: Alluvium
REMARKS: Some bare spots

0-12, v. sti., mod. salt streaks
12-28, v. stl., mod. salt streaks
28-36, v. fri.
36-48, v. fri., mod. sti.
48-64, v. fri., v. sti.
64-90, v. fri., v. stl.
90-100, v.fri., sl. sti.
100-120, v. fri., mod. sti.



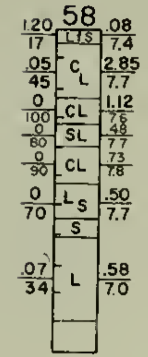
LOCATION: 500'S, 300'E, NW Cor. Sec. 17
PARENT MATERIAL: Alluvium
REMARKS: Area sl. low, just N. of old lakebed

0-10, soft, mod. sti.
10-24, hard, sti.
24-36, sl. hard, sl. sti.
36-56, mod. hard, sti.
56-72, sl. hard, sl. stl.
72-108, sl. hard, sti.
108-120, mod. hard, sti., raw-almost weathered shale



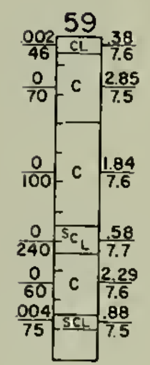
LOCATION: 2525'E, 175'S, NW Cor. Sec. 17
PARENT MATERIAL: Alluvium
REMARKS: Profile at core drilling site 5

0-12, surf. 3" hard then soft
12-44, soft, 44-54, SCL, no sample
54-90, mod. hard, mod. sti.
90-120, mod. hard, mod. sti., sl. discoloration at 104"



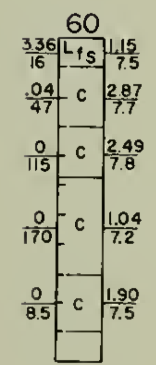
LOCATION: 350'N, 250'W, SE Cor. Sec. 17
PARENT MATERIAL: Eolian
REMARKS: Sandy surf. area

0-6, soft
6-28, mod. hard and stl., mod. salt mott.
28-38, mod. hard, sl. sti.
38-48, sl. hard and compact
48-64, sl. hard, mod. sti.
64-80, v. sl. hard,
80-86, S, no sample
86-120, soft



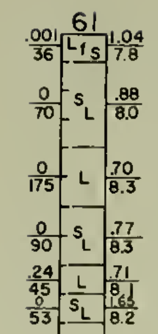
LOCATION: 500'N, 500'W, SE Cor. Sec. 17
PARENT MATERIAL: Eolian
REMARKS: Bare spot, scattered shallow sandy areas

0-6, mod. hard, sl. sti.
6-36, hard, v. sti., mod. salt mott.
36-78, hard, v. sti., sl. salt mott.
78-88, mod. hard, mod. sti.
88-114, v. hard, v. sti.
114-120, sl. hard, mod. sti.



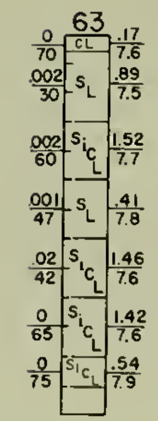
LOCATION: 1800'N, 700'W, SE Cor. Sec. 17
PARENT MATERIAL: Alluvium
REMARKS: Small shallow blowouts

0-12, soft
12-36, mod. hard, v. pls. and stl., st. salt mott.
36-58, v. hard, v. pls. and stl., sl. salt mott.
58-96, mod. hard, v. pls. and sti., v. thin zone of SCL at 72"
96-120, v. hard and tough, v. pls. and stl., sl. salt mott.



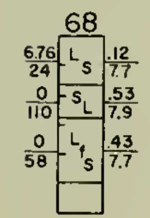
LOCATION: 1300'S, 1700'W, NE Cor. Sec. 17
PARENT MATERIAL: Eolian
REMARKS: On ridge between badland and sandy area

0-12, mod. cemented
12-48, v. cemented
48-72, v. cemented, sl. salt streaks
72-96, v. cemented, sl. salt streaks
96-108, v. hard and cem., mod. stl.
108-120, v. cem., sl. sti.



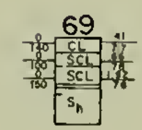
LOCATION: 700'S, 150'W, NE Cor. Sec. 17
PARENT MATERIAL: Alluvium
REMARKS: Area has v. sparse vegetation

0-6, v. sti., sl. pls.
6-36, mod. cem. 24"-36"
36-60, sl. sti., mod. hard
60-84, soft
84-108, mod. hard, v. stl., sl. salt mott.
108-132, mod. hard, v. sti., sl. salt mott.
132-144, mod. hard, mod. sti.



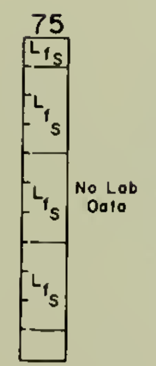
LOCATION: 2150'N, 125'W, SE Cor. Sec. 17
PARENT MATERIAL: Eolian
REMARKS: Sandy area

0-20, v. fri.
20-34, mod. fri., mod. stl. and pls.
34-60, v. fri., mod. sti.



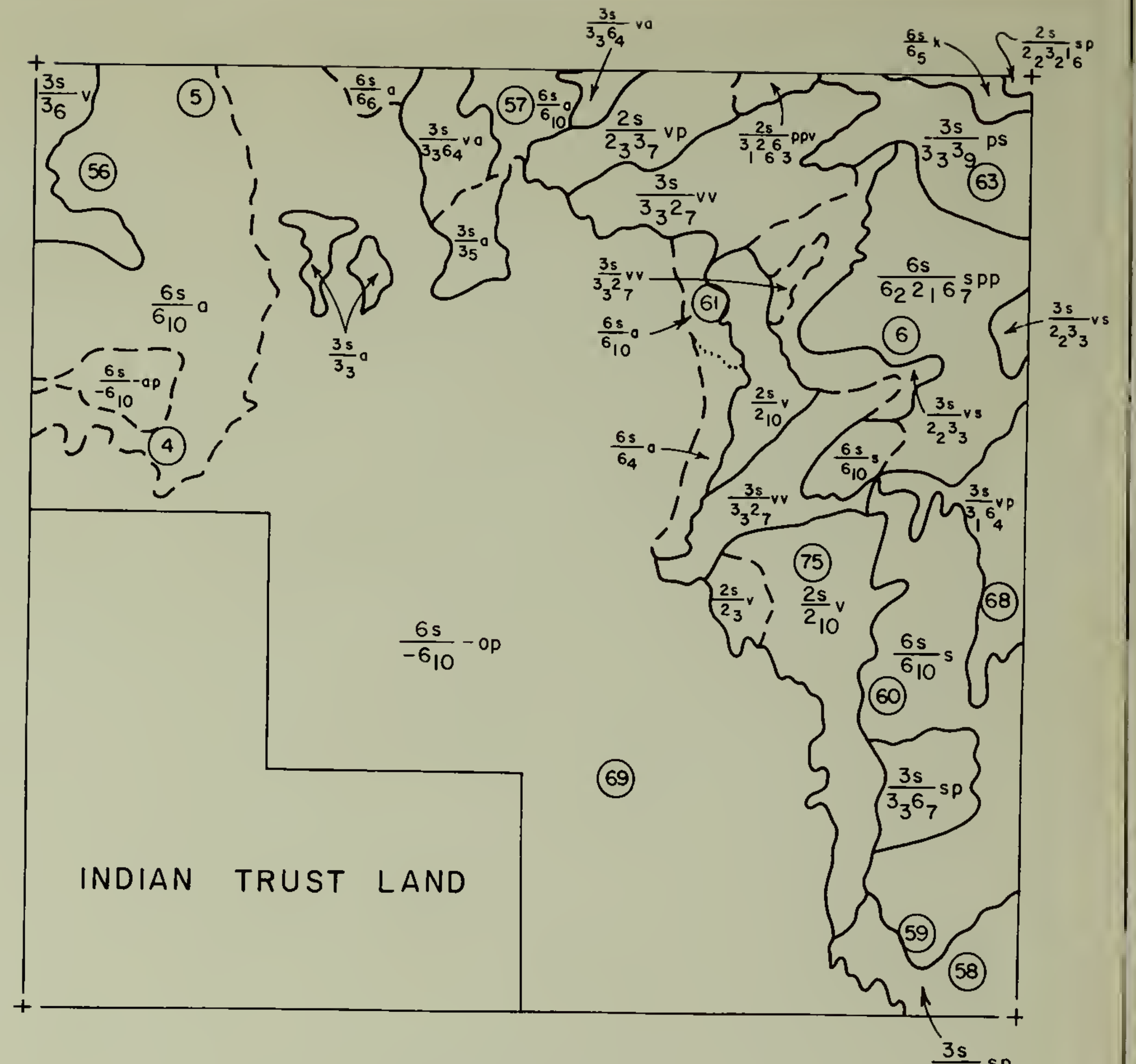
LOCATION: 2200'W, 1175'N, SE Cor. Sec. 17
PARENT MATERIAL: Alluvium
REMARKS: Shallow soils throughout area

0-6, pls. and sti.
6-12, pls. and sti.
12-18, pls. and sti.
18+, sh



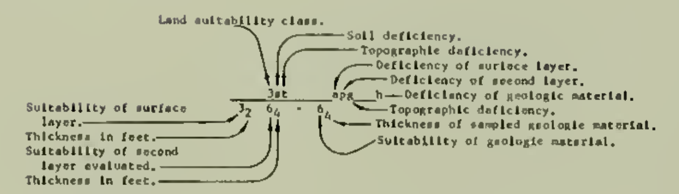
LOCATION: 1100'W, 2400'N, SE Cor. Sec. 17
PARENT MATERIAL: Eolian
REMARKS: Sandy area on mesa

0-12, loose
12-48, sl. compact
48-84, loose
84-120, sl. compact



SECTION 17

<u>Mapping and Profile Symbols for Land Classification</u>

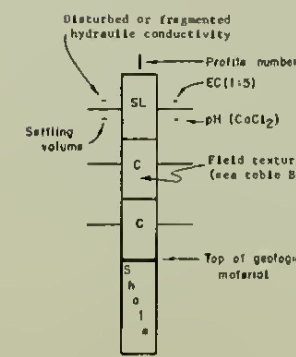


Land class suitability
1 good
2 fair
3 poor
6 unsuitable

Subclasses
s - soils
t - topography

Subclass deficiency
v - very coarse texture
s - sodic
p - permeability
s - saline
k - shallow depth to coarse sand, gravel, or cobble
g - slope

Profile Description



Textures

S	sand
fS	fine sand
VfS	very fine sand
LfS	loamy fine sand
LS	loamy sand
fSL	fine sandy loam
SL	sandy loam
L	loam
SiL	silty loam
CL	clay loam
SiCL	silty clay loam
SCL	sandy clay loam
SiC	silty clay
SC	sandy clay
C	clay
Sh	shale
SS	sandstone

LEGEND

2s/2_3 1_2 6_5 vs LAND CLASS

(3) PROFILES

——— SEPARATES CLASSES
– – – SEPARATES SUBCLASSES
.... SEPARATES DEPTHS WITHIN SAME CLASS

LAND CLASS**	ACRES
1	0
2	45
3	93
TOTAL	148
6	372
ITL	120
GRAND TOTAL	640

** FOR COMPLETE ACREAGE OF EACH INDIVIDUAL LAND CLASSIFICATION SEE TABLE B-2

* LANDS WERE CLASSIFIED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

BISTI WEST STUDY SITE

PROFILE DESCRIPTIONS* AND LAND CLASSIFICATION

EMRIA REPORT NO. 5-1976

FIGURE B-4

Table B-2

Land Class Acreages

LAND CLASS	SEC. 6	SEC. 7	SEC. 8	SEC. 17	TOTAL
$\frac{1}{1_6 3_5 2_4}vv$	56	0	0	0	56
TOTAL CLASS 1	56				56
$\frac{2s}{2_3}v$	0	5	28	3	36
$\frac{2s}{2_{10}}v$	0	0	0	29	29
$\frac{2s}{2_5 3_3 2_2}vvv$	0	0	11	0	11
$\frac{2s}{1_1 2_3 3_2}vp$	2	0	0	0	2
$\frac{2s}{2_3 6_2}va$	0	9	10	0	19
$\frac{2s}{2_4 6_6}va$	0	0	8	0	8
$\frac{2s}{2_3 3_7}vp$	0	0	1	10	11
$\frac{2s}{2_2 3_2 1_6}sp$	0	0	7	1	8
$\frac{2s}{2_3 3_2 6_5}vps$	0	18	0	0	18
$\frac{2s}{2_4 1_2 \cdot 2_1 6_3}vas$	0	6	17	0	23
$\frac{2s}{2_4 3_4 3_2}vsv$	0	0	24	0	24
$\frac{2s}{3_1 2_6 6_3}ppv$	0	0	2	2	4
TOTAL CLASS 2	2	38	108	45	193

Table B-2 cont.

Land class	Sec. 6	Sec. 7	Sec. 8	Sec. 17	Total
$\frac{3s}{3_2}v$	10	0	0	0	10
$\frac{3s}{3_4}v$	5	19	0	0	24
$\frac{3s}{3_6}v$	10	26	0	6	42
$\frac{3s}{3_{10}}v$	9	0	47	0	56
$\frac{3s}{3_3}a$	0	0	0	3	3
$\frac{3s}{3_5}a$	0	0	0	4	4
$\frac{3s}{2_1 6_3}va$	0	2	0	0	2
$\frac{3s}{3_3 2_7}vv$	0	0	0	30	30
$\frac{3s}{2_2 3_3}vs$	0	0	0	12	12
$\frac{3s}{3_1 6_4}vp$	0	10	0	0	10
$\frac{3s}{3_3 6_7}sp$	0	0	0	17	17
$\frac{3s}{3_3 1_4 3_5}vv$	46	0	0	0	46
$\frac{3s}{3_7 3_3}vp$	10	23	0	0	33
$\frac{3s}{3_1 6_5}as$	0	18	0	0	18
$\frac{3s}{3_3 6_4}va$	0	11	3	8	22
$\frac{3s}{3_1 6_9}pa$	0	15	0	0	15
$\frac{3s}{3_3 3_9}ps$	0	0	1	13	14

Table B-2 cont.

Land Class Acreages

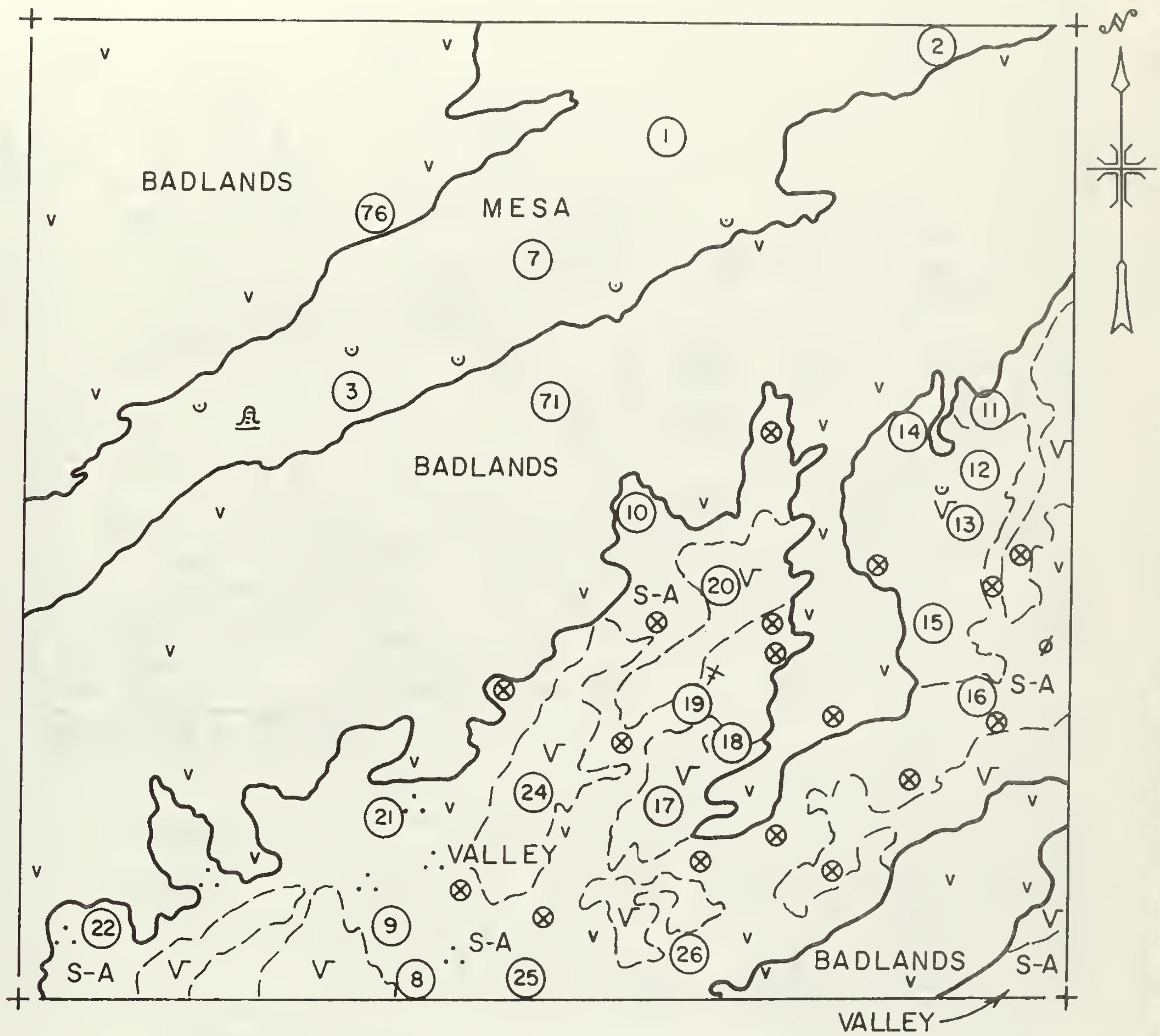
Land class	Sec. 6	Sec. 7	Sec. 8	Sec. 17	Total
$\frac{3s}{3_4 6_3 6_3}$ vap	17	0	0	0	17
$\frac{3s}{3_7 3_4 2_2}$ vps	10	0	0	0	10
$\frac{3s}{2_1 6_5 3_2}$ vap	8	0	0	0	8
$\frac{3s}{3_1 3_2 2_3}$ vas	5	0	0	0	5
$\frac{3s}{3_3 6_2 2_2}$ vas	1	0	0	0	1
$\frac{3s}{3_1 6_4 6_3}$ spa	0	10	0	0	10
$\frac{3s}{3_2 6_4 3_2}$ sps	0	23	0	0	23
$\frac{3s}{2_1 6_2 - 6_6}$ vp-a	0	4	0	0	4
TOTAL CLASS 3	131	161	51	93	436
$\frac{6s}{6_6}$ v	0	33	19	0	52
$\frac{6s}{6_5}$ k	0	11	42	2	55
$\frac{6s}{6_1}$ a	44	7	1	0	52
$\frac{6s}{6_4}$ a	31	14	20	5	70
$\frac{6s}{6_6}$ a	3	12	44	2	61
$\frac{6s}{6_{10}}$ a	36	241	90	54	421
$\frac{6s}{6_{10}}$ sa	0	0	17	0	17

Land class	Sec. 6	Sec. 7	Sec. 8	Sec. 17	Total
$\frac{6s}{6_{10}}$ s	0	0	0	34	34
$\frac{6s}{6_1 6_4}$ av	0	1	88	0	89
$\frac{6s}{6_3 6_7}$ sp	0	15	0	0	15
$\frac{6s}{6_1 6_4 6_3}$ spa	0	9	0	0	9
$\frac{6s}{6_2 2_1 6_7}$ spp	0	0	0	27	27
$\frac{6s}{-6_{10}}$ -ap	92	38	58	248	436
$\frac{6s}{6_1 - 6_2}$ s-p	0	30	0	0	30
$\frac{6s}{6_1 - 6_2}$ a-p	0	0	22	0	22
$\frac{6s+}{-6_{10}}$ -apg	245	0	0	0	245
TOTAL CLASS 6	451	411	401	372	1635

Table B-2 cont.

Land Class Acreages

	SEC 6	SEC 7	SEC 8	SEC 17	TOTAL
class 1	56	0	0	0	56
class 2	2	38	108	45	193
class 3	131	161	51	93	436
TOTAL	189	189	159	148	685
Class 6	451	411	401	372	1635
INDIAN TRUST LAND	0	40	80	120	240
GRAND TOTAL	640	640	640	640	2560



Mapping Symbols

- Hummocks
- Blowout
- Clay spot
- Gravelly spot
- Gumbo, Slick or Scaby Spot (sodic)
- v – Rock outcrop (includes Shale & Sandstone)
- Baked rock (scoria)
- \# – Greasewood
- (3) – Profiles
- ⊗ – Check holes
- — — — Separates valley subcategories

MAJOR LAND CATEGORIES

	ACRES		ACRES
MESA	102	*MISCELLANEOUS*	
BADLANDS	340	*ACTIVE DUNES*	0
VALLEY		*HUMMOCKY*	0
V- sandy	79	*STREAM CHANNEL*	0
		TOTAL	640
S-A saline-sodic	119	INDIAN TRUST LAND	0
		GRAND TOTAL	640

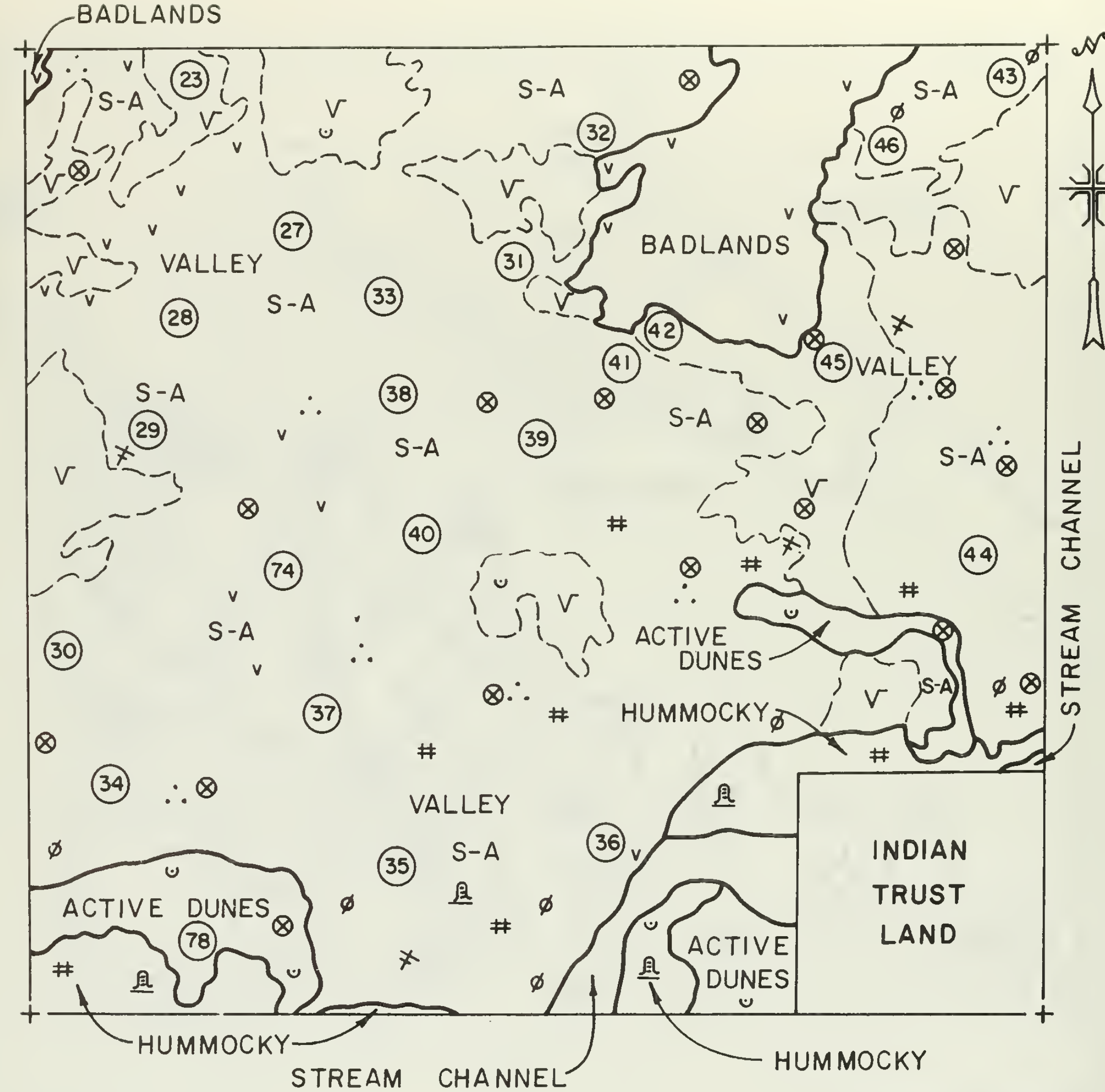
SECTION 6

EMRIA REPORT NO. 5 -1976

SCALE 1 : 12,000

1000 0 1000 Ft.

FIGURE B-5



Mapping Symbols

- Hummocks
- Blowout
- Clay spot
- Gravelly spot
- ø – Gumbo, Slick or Scaby Spot (sodic)
- v – Rock outcrop (includes Shale & Sandstone)
- Baked rock (scoria)
- # – Greasewood
- (3) – Profiles
- ⊗ – Check holes
- — — — Separates valley subcategories

MAJOR LAND CATEGORIES

	ACRES		ACRES
MESA	0	***MISCELLANEOUS***	
BADLANDS	39	*ACTIVE DUNES*	31
VALLEY		*HUMMOCKY*	25
V̄- sandy	91	*STREAM CHANNEL*	11
S-A saline-sodic	403	TOTAL	600
		INDIAN TRUST LAND	40
		GRAND TOTAL	640

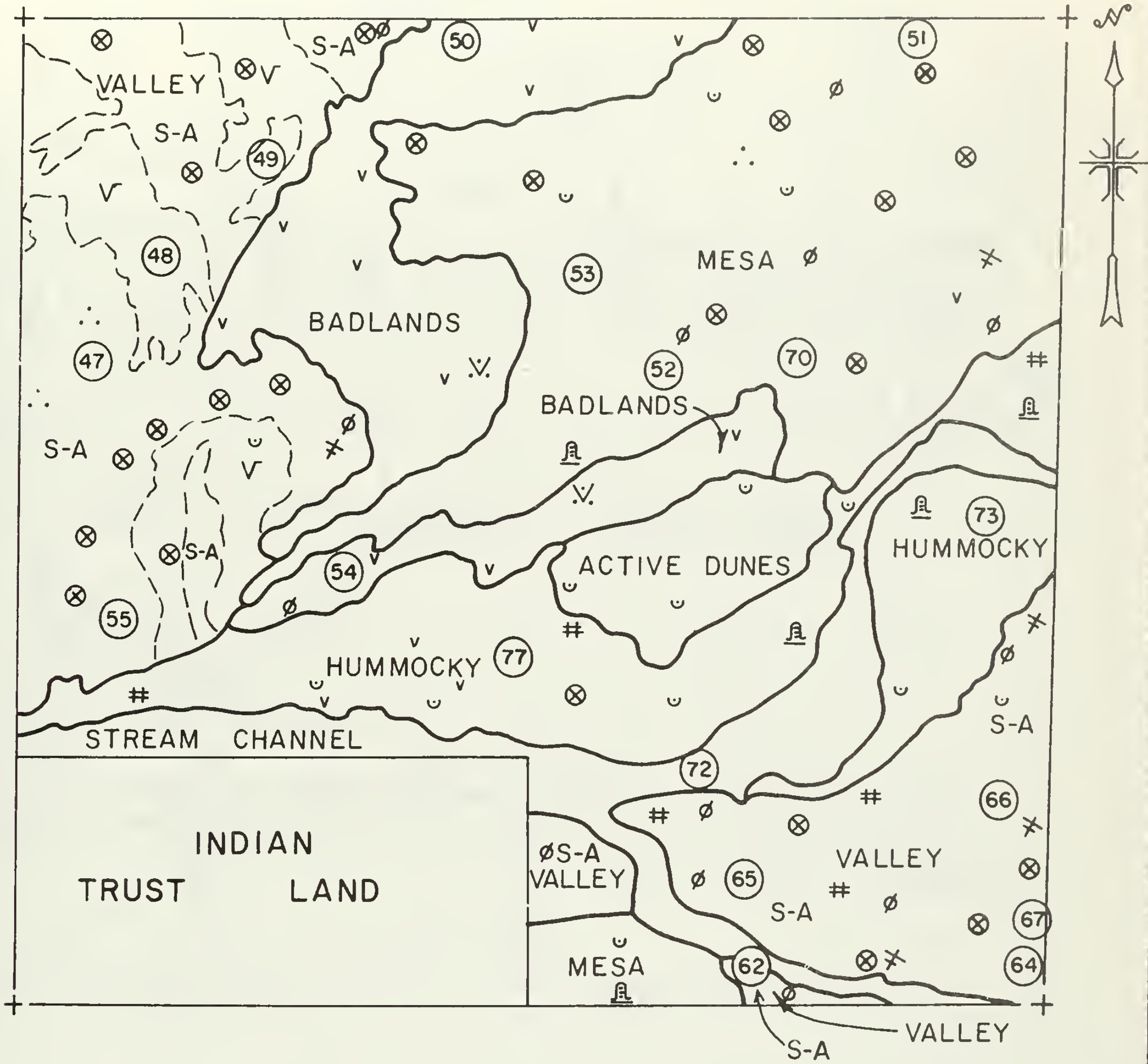
SECTION 7

EMRIA REPORT NO. 5 -1976

SCALE 1 : 12,000

1000 0 1000 Ft.

FIGURE B-6



Mapping Symbols

- Hummocks
- Blowout
- Clay spot
- Gravelly spot
- Ø – Gumbo, Slick or Scaby Spot (sodic)
- v – Rock outcrop (includes Shale & Sandstone)
- Boked rock (scoria)
- # – Greasewood
- (3) – Profiles
- ⊗ – Check holes
- – – – Separotes volley subcotegories

MAJOR LAND CATEGORIES

	ACRES		ACRES
MESA	161	*MISCELLANEOUS*	
BADLANDS	76	*ACTIVE DUNES*	20
VALLEY		*HUMMOCKY*	87
V- sandy	38	*STREAM CHANNEL*	41
S-A saline-sodic	137	TOTAL	560
		INDIAN TRUST LAND	80
		GRAND TOTAL	640

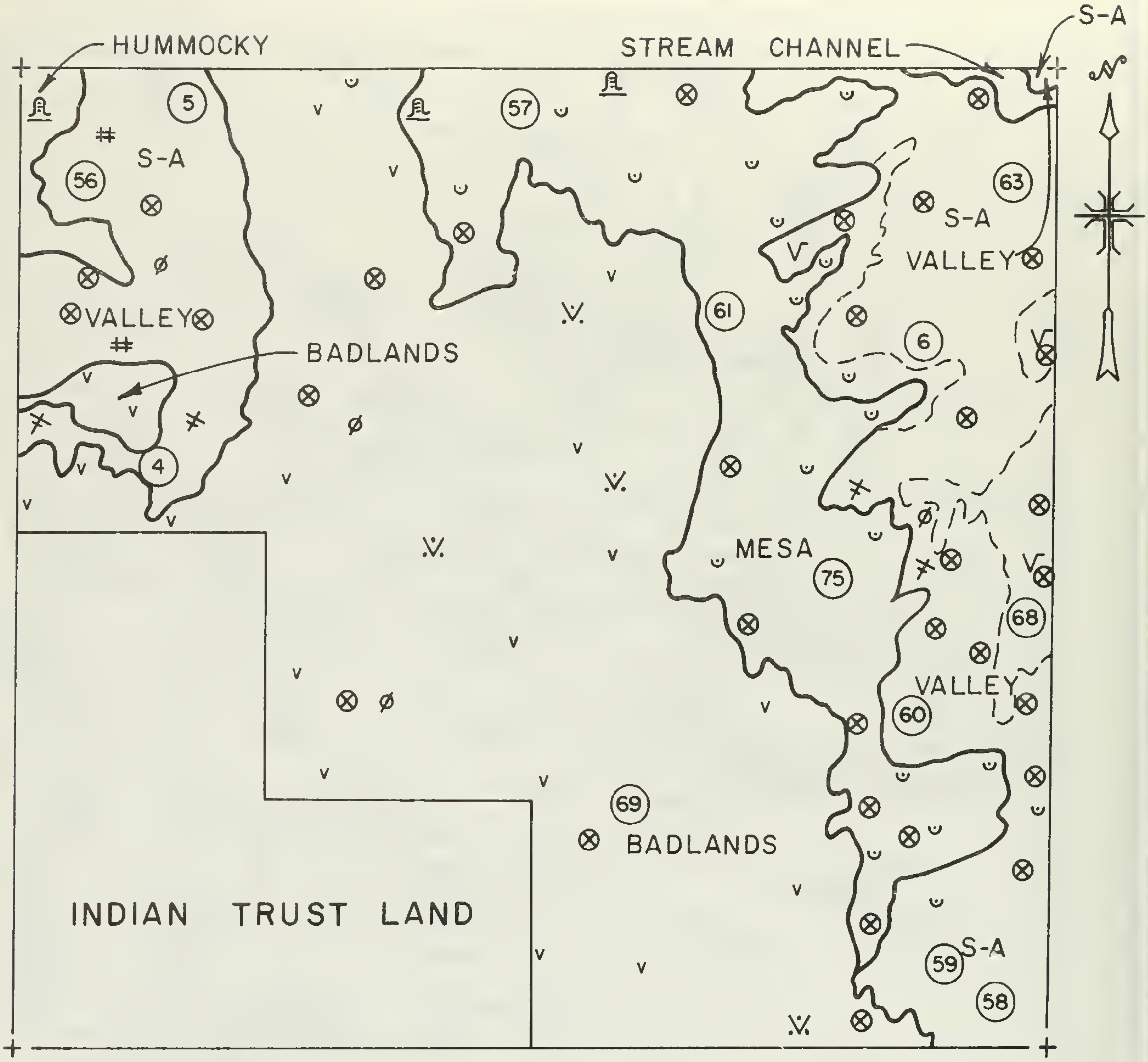
SECTION 8

EMRIA REPORT NO. 5 -1976

SCALE 1 : 12,000

1000 0 1000 Ft

FIGURE B-7



Mapping Symbols

- Hummocks
- Blowout
- Clay spot
- Gravelly spot
- ø – Gumbo, Slick or Scaby Spot (sodic)
- v – Rock outcrop (includes Shale & Sandstone)
- Baked rock (scoria)
- # – Greasewood
- (3) – Profiles
- ⊗ – Check holes
- — — — Separates valley subcategories

MAJOR LAND CATEGORIES

	ACRES		ACRES
MESA	103	*MISCELLANEOUS*	
BADLANDS	255	*ACTIVE DUNES*	0
VALLEY		*HUMMOCKY*	7
V-sandy	20	*STREAM CHANNEL*	3
S-A saline-sodic	132	TOTAL	520
		INDIAN TRUST LAND	120
		GRAND TOTAL	640

SECTION 17

EMRIA REPORT NO. 5 -1976

SCALE 1 : 12,000

1000 0 1000 Ft.

FIGURE B-8

PROGRESS REPORT

Results of Weathering Tests
Conducted on Core Samples
from Coal-Mined Areas

Objectives

Laboratory weathering tests were conducted on overburden core samples from the four sites listed below to determine which materials would break down sufficiently to allow for their possible use as a planting media in revegetation of strip-mined areas.

The site and number of core samples tested under each condition are as follows:

Site	Number of samples tested		
	Freeze-thaw	Wet-dry	Outdoor
Red Rim, Wyoming	9	9	9
Bear Creek, Montana	11	11	11
Horse Nose Butte, North Dakota	9	9	7
Bisti West, New Mexico	21	21	21

Results of laboratory weathering tests conducted on core samples from four other sites were reported previously in Applied Science Referral Memorandum No. 75-1-2, dated March 28, 1975.

Test Procedures

Specimens for the freeze-thaw, wet-dry, and outdoor tests were cut from core samples submitted by regional personnel.

The purpose of including outdoor exposure tests was to determine if any correlation could be drawn between this type of weathering and the freeze-thaw and wet-dry conditions.

A freeze-thaw cycle consisted of the following conditions:

1. 8 hours at 23.9°C (75°F), 100 percent relative humidity (wetting/thawing)

2. 16 hours (64 hours on weekend) at -17.8°C (0°F) (freezing)

For the wet-dry tests, one cycle consisted of:

1. 8 hours at 23.9°C (75°F), 100 percent relative humidity (wetting)

2. 16 hours (64 hours on weekends) at 37.8°C (100°F), 10 percent relative humidity (drying)

Except for samples from Red Rim, core specimens about 5 cm (2 in.) in diameter by 5 cm (2 in.) in length were used. The core specimens from Red Rim were 10.2 cm (4 in.) in diameter by 2.5 cm (1 in.) in length. For testing and handling the smaller core specimens were placed on a No. 10 mesh screen in 400-ml plastic beakers. The Red Rim specimens were placed in 1-quart waxed cardboard containers.

Tests were started on December 23, 1975, and 43 laboratory weathering cycles were completed on March 1, 1976. For the outdoor exposure specimens, 10 weeks of testing were completed on March 2, 1976. During this 10-week period, the specimens were subjected to approximately 2.5 cm (1 in.) of precipitation from about seven snowstorms. Also, it is estimated that from 40 to 50 freeze-thaw cycles occurred during this period. For example, during January the temperature range for freeze-thaw occurred on 26 of 31 days.

The test specimens were visually examined about once a week to monitor changes. Also, to provide a visual record of the tests, photographs, both black/white and 35-mm color slides, were taken before and after testing on 11 core samples representing various soil types.

Test Results

Results of visual examinations are summarized in tabular form at the end of this report. Illustrated in figure 1 are several of the terms listed under the remarks column in the tables to describe the various breakdown patterns noted during testing. Further, the term "saturated" as used in this report denotes the condition in which free water was observed on the surface of the specimen (figure 1c). The term "swelling" was used when an increase in specimen size was noted (figure 1c). Quite often this swelling resulted in a mushroom appearance.

At the completion of the 43 weathering cycles, a percent breakdown value (%BD) was determined for a number of the specimens. This value listed under the remark column in the tables was derived as follows:

$$\%BD = \frac{TW-IW}{TW} = 100$$

Where

TW = Total specimen weight
IW = Weight of original specimen remaining intact after testing

In the freeze-thaw tests, the specimens were not allowed to dry out, and the continual wetting caused the specimens to become saturated: this resulted in many cases in breakdown or swelling. For these specimens the %BD was considered to be 100.

For future laboratory weathering tests it is recommended that the samples be subjected to alternate freeze-thaw and wet-dry cycles. This would eliminate the continual wetting process for the freeze-thaw specimens, and it would simulate more closely the outdoor weathering as observed in this study.

The outdoor specimens will continue to be monitored, and a subsequent report will be prepared summarizing the results. Test results for samples from the study site are discussed in the following paragraphs.

Test Results - Bisti West, New Mexico

Test results are summarized in table B-3 and figures (photos) BW-1, BW-2, and BW-3.

Of the 21 samples tested, the following 5 appeared to have broken down sufficiently for possible use as a planting media: silty shale, BW-1-4-75[1/] depth 103 feet; shale, BW-1-*-75, depth 283 feet; sandstone, BW-2-5-75, depth 64 feet; sandstone, BW-2-*-75, depth 157 feet; and siltstone, BW-6-4-75, depth 77 feet. However, except for the sandstone material, these samples exhibited swelling characteristics and might be somewhat difficult to handle and place in a moist condition during revegetation work. It should be noted that a majority of the freeze-thaw specimens were susceptible to swelling upon wetting.

A dry gradation analysis was obtained on three freeze-thaw specimens and the results are listed below:

---

drill hole (DH) number

1/ BW-1-4-75

sample number

Table B-2a

Weathering Tests - Dry Gradation Analysis

Shale, BW-1-*-75, depth 283 feet

Sieve size	Cumulative percent passing	Description
4	45.5	(DH-1)
10	36.6	Fruitland Formation
50	3.1	shale, clayey, gypsum,
100	1.1	seams (1/8")
200	0.5	

Sandstone, BW-2-*-75, depth 157 feet

Sieve size	Cumulative percent passing	Description
4	80.1	(DH-2)
10	61.4	Fruitland Formation
50	24.2	siltstone, clayey,
100	11.1	firm, laminated, gray
200	5.3	

Siltstone, BW-2-*-75, depth 157.5 feet

Sieve size	Cumulative percent passing	Description
4	15.3	(DH-2)
10	12.1	Fruitland Formation
50	9.7	siltstone, clayey,
100	8.9	firm, laminated, gray
200	7.8	

Acknowledgement

Laboratory photographic work by W. M. Batts.

Table B-3

WEATHERING TESTS

Core Samples from Bisti West, New Mexico

Sample I.D.	Formation	Remarks
Shale BW-1-1-75* Depth (ft) 37.5 (BW-1)**	Kirtland	(See photograph BW-1) Freeze-thaw: Saturated and swelling at 9 cycles. %BD = 100 Wet-dry: cracking at 3 cycles, slight slaking at 12 cycles, the cracking at 43 cycles is very similar to that noted for outdoor sample at 10 weeks. %BD = less than 1 Outdoor: cracking noted at 1 week, slight peeling at 2 weeks, continued cracking at 10 weeks
Sandstone BW-1-3-75 Depth (ft) 66.0 (BW-2)	Kirtland	Freeze-thaw: Slight swelling at 6 cycles, saturated at 15 cycles. %BD = 100 Wet-dry: Slight surface peeling at 6 cycles, slight slaking at 15 cycles, continuous surface peeling at 43 cycles. %BD = less than 1 Outdoor: Cracking noted at 2 weeks, continued cracking noted at 10 weeks
Silty shale BW-1-4-75 Depth (ft) 103.0 (BW-3)	Kirtland	Freeze-thaw: Swelling and slaking at 6 cycles. %BD = 100 Wet-dry: Surface peeling at 9 cycles, slight slaking at 15 cycles, continuous slaking at 43 cycles, this slaking is very similar to that noted for outdoor sample at 10 weeks. %BD = 20.5 Outdoor: Cracking and some slaking noted at 1 week, cleaving noted at 4 weeks, some breakdown at 10 weeks

Table B-3

WEATHERING TESTS

Core Samples from Bisti West, New Mexico

Sample I.D.	Formation	Remarks
Silty sandstone BW-1-5-75 Depth (ft) 134.0 (BW-4)	Kirtland	Freeze-thaw: Slight swelling at 6 cycles, saturated and swelling at 15 cycles. %BD = 100 Wet-dry: Surface peeling at 9 cycles, continued surface peeling at 43 cycles. %BD = less than 1 Outdoor: Slight cracking at 3 weeks, cracking and surface peeling at 10 weeks
Siltstone BW-1-5-75 Depth (ft) 154.0 (BW-5)	Kirtland	Freeze-thaw: Saturated and swelling at 15 cycles. %BD = 100 Wet-dry: Slaking at 9 cycles, cracking at 43 cycles is very similar in appearance to that noted for outdoor sample at 10 weeks. %BD = 3 Outdoor: Cracking at 4 weeks, continued cracking at 10 weeks
Sandstone BW-1-6-75 Depth (ft) (BW-6)		Freeze-thaw: Saturated and swelling at 15 cycles. %BD = 100 Wet-dry: Surface peeling at 12 cycles, continued peeling at 43 cycles. %BD = less than 1 Outdoor: Slight cracking at 3 weeks, cracking and slight peeling at 10 weeks
Siltstone BW-1-*-75 Depth (ft) 226.0 (BW-7)	Fruitland	Freeze-thaw: Slight swelling at 3 cycles, cleaving at 6 cycles, swelling at 12 cycles. %BD = 100 Wet-dry: Slight slaking at 9 cycles, cracking at 43 cycles is very similar in appearance to that noted for outdoor sample at 10 weeks. %BD = less than 1 Outdoor: Cracking at 1 week, continued cracking at 10 weeks

Table B-3

WEATHERING TESTS

Core Samples from Bisti West, New Mexico

Sample I.D.	Formation	Remarks
Shale BW-1-*-75 Depth (ft) 283.0 (BW-8)	Fruitland	Freeze-thaw: Slaking and slight swelling at 3 cycles, severe slaking at 6 cycles, severe swelling at 9 cycles. %BD = 100 Wet-dry: Slight cracking at 6 cycles, slaking at 12 cycles, cracking at 43 cycles is less severe than that noted for outdoor sample at 10 weeks. %BD = 13 Outdoor: Slaking at 1 week, severe slaking and cleaving at 3 weeks, at 10 weeks this sample has exhibited more weathering than wet-dry sample.
Sandstone BW-2-*-75 Depth (ft) (BW-9)	Fruitland	Freeze-thaw: Slaking at 9 cycles, saturated and swelling at 12 cycles. %BD = 100 Wet-dry: Peeling at 9 cycles, slaking at 20 cycles, the slaking and cracking at 43 cycles are very similar in appearance to that noted for outdoor sample at 10 weeks. %BD = 4.5 Outdoor: Some slaking on side of sample at 1 week, continued cracking at 10 weeks
Sandstone BW-2-5-75 Depth (ft) 64.0 (BW-10)	Fruitland	Freeze-thaw: Swelling at 12 cycles, saturated at 15 cycles. %BD = 100 Wet-dry: Surface peeling at 9 cycles, cracking and continuous surface peeling at 43 cycles is very similar in appearance to that noted for outdoor sample at 10 weeks. %BD = 36.5 Outdoor: Slight surface peeling at 4 weeks, cracking and additional surface peeling at 10 weeks

Table B-3

WEATHERING TESTS

Core Samples from Bisti West, New Mexico

Sample I.D.	Formation	Remarks
Sandstone BW-2-*-75 Depth (ft) 67.0-68.5 (BW-11)	Fruitland	Freeze-thaw: Small portion of top edge slightly weathered at 43 cycles. %BD = less than 1 Wet-dry: No change at 43 cycles Outdoor: No change at 10 weeks
Sandstone BW-2-6-75 Depth (ft) 88.0 (BW-12)	Fruitland	Freeze-thaw: Swelling at 12 cycles, saturated at 15 cycles. %BD = 100 Wet-dry: Some blistering of surface at 12 cycles, cracking and slight surface peeling at 43 cycles. %BD = less than 1 Outdoor: Very slight cracking at 10 weeks
Sandstone BW-2-*-75 Depth (ft) 157.0 (BW-13)	Fruitland	Freeze-thaw: Sample slightly friable on bottom surface at 12 cycles, saturated at 35 cycles. %BD = 100 Wet-dry: Slight cracking at 43 cycles. %BD = less than 1 Outdoor: Slight cracking at 3 weeks, cracking at 10 weeks is more severe than that noted for wet-dry sample
Siltstone BW-2-*-75 Depth (ft) 157.5 (BW-14)	Fruitland	(See photograph BW-2) Freeze-thaw: Swelling and some slaking at 6 cycles, saturated at 35 cycles. %BD = 100 Wet-dry: Surface peeling at 9 cycles, slaking at 12 cycles, continuous slaking at 43 cycles. %BD = 18 Outdoor: Cracking at 2 weeks, continued cracking at 10 weeks

Table B-3

WEATHERING TESTS

Core Samples from Bisti West, New Mexico

Sample I.D.	Remarks
Sandstone BW-4-2-75 Depth (ft) 91.0-92.0 (BW-15)	Freeze-thaw: Swelling at 12 cycles, saturated at 15 cycles. %BD = 100 Wet-dry: Surface peeling at 12 cycles, cracking and continuous surface peeling at 43 cycles. %BD = less than 1 Outdoor: No change at 10 weeks
Sandstone BW-5-3-75 Depth (ft) 94.0 (BW-16)	Freeze-thaw: Swelling at 9 cycles, saturated at 15 cycles. %BD = 100 Wet-dry: Slight surface peeling at 15 cycles, slight cracking at 43 cycles. %BD = less than 1 Outdoor: No change at 10 weeks
Sandstone BW-6-2-75 Depth (ft) 53.5 (BW-17)	Freeze-thaw: Swelling at 9 cycles, severe swelling at 12 cycles, saturated at 15 cycles. %BD - 100 Wet-dry: Surface peeling at 12 cycles, some blistering of surface at 35 cycles, cracking and continuous surface peeling at 43 cycles are very similar in appearance to that noted for outdoor sample at 10 weeks. %BD = less than 1 Outdoor: Slight cracking at 3 weeks, cracking and surface peeling at 10 weeks
Siltstone BW-6-4-75 Depth (ft) 77.0 (BW-18)	Freeze-thaw: Slight swelling at 3 cycles, severe swelling at 6 cycles, saturated at 15 cycles. %BD = 100 Wet-dry: Slight cracking at 6 cycles, slight slaking at 12

Table B-3

WEATHERING TESTS

Core Samples from Bisti West, New Mexico

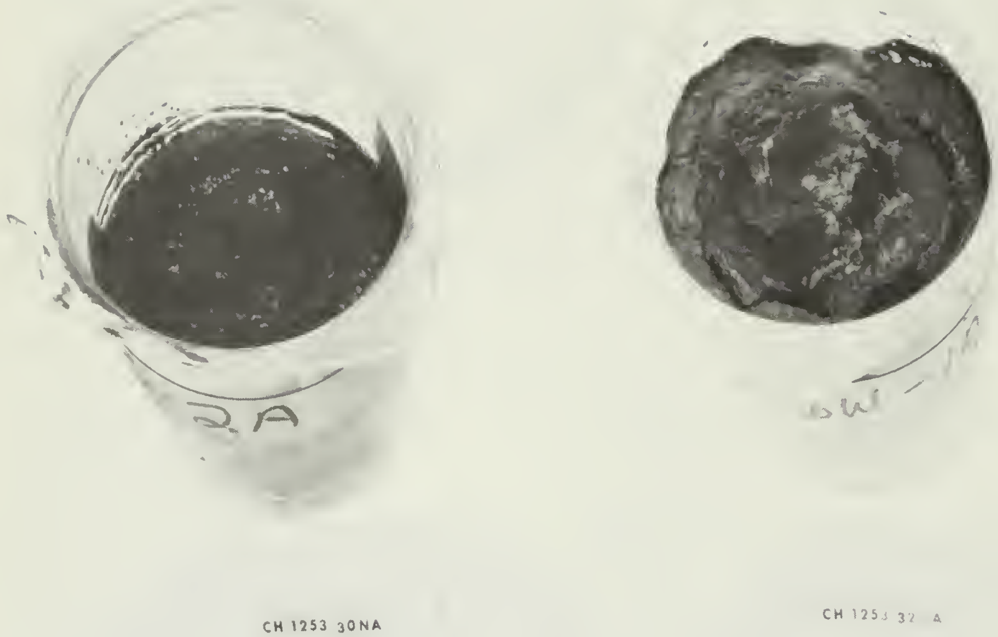
Sample I.D.	Remarks
Siltstone (continued)	cycles, no appreciable change in sample at 43 cycles. %BD = 5.5 Outdoor: Slight cracking and slight slaking at 1 week, some cleaving at 3 weeks, at 10 weeks sample has exhibited more breakdown than wet-dry sample
Sandstone BW-6-5-75 Depth (ft) 111.0 (BW-19)	(See photograph BW-3) Freeze-thaw: Slight swelling at 15 cycles, saturated at 35 cycles. %BD = 100 Wet-dry: No change at 43 cycles Outdoor: No change at 10 weeks
Sandstone BW-7-7-75 Depth (ft) 130.0 (BW-20)	Freeze-thaw: Saturated at 9 cycles, swelling at 15 cycles. %BD = 100 Wet-dry: Some blistering of surface at 12 cycles, continued blistering at 43 cycles. %BD = less than 1 Outdoor: Very slight cracking at 10 weeks
Sandstone BW-7-*-75 Depth (ft) 177.0 (BW-21)	Freeze-thaw: Saturated at 35 cycles. %BD = 100 Wet-dry: No change at 43 cycles Outdoor: No change at 10 weeks

*Field sample number.
**Laboratory sample number.

a. Cracking,peeling (left); cracking (right).

b. Cleaving (left); slaking (right).

Examples of typical distress patterns noted during laboratory weathering tests.
Figure 1



c. Saturated (left); swelling (right)

Examples of typical distress patterns noted during laboratory weathering tests.
Figure 1 (continued)

a. Original condition.

b. Condition after 43 weathering cycles for A and B, and 10 weeks of outdoor exposure for C.

Figure BW-1. Results of laboratory weathering for shale sample from Bisti West, New Mexico; BW-1-1-75, depth 37.5'. Sample A on left was subjected to freeze-thaw; Sample B in center was subjected to wet-dry; and Sample C was subjected to outdoor weathering.

a. Original condition.

b. Condition after 43 weathering cycles for A and B, and 10 weeks of outdoor exposure for C.

Figure BW-2. Results of laboratory weathering for siltstone sample from Bisti West, New Mexico; BW-2-*-75, depth 157.5'.

a. Original condition.

b. Condition after 43 weathering cycles for A and B, and 10 weeks of outdoor exposure for C.

Figure BW-3. Results of laboratory weathering for sandstone sample from Bisti West, New Mexico; BW-6-5-75, Depth 111.0'.

RESULTS OF GREENHOUSE STUDIES

Characterization of Strata Overlying Coal Seams as Plant Growth Media

This greenhouse study*was carried out in cooperation with and supplements ongoing work of the U.S. Bureau of Reclamation and the U.S. Bureau of Land Management.

Contract 6-07-DR-50310 U.S. Bureau of Reclamation

Prepared by

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January 1977

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* Only excerpts from this study which pertain to the Bisti West study site are presented.

ABSTRACT

Western wheatgrass was grown on overburden samples from six potential federal coal lease sites:

1. Bear Creek, Montana
2. Horse Nose Butte, North Dakota
3. Red Rim, Wyoming
4. Bisti West, New Mexico
5. Foidel Creek, Colorado
6. White Tail Butte, Wyoming

These samples included soil profile samples and geologic samples from core holes drilled by the U.S. Bureau of Reclamation. In this greenhouse study, 2.0 kg of each overburden sample was weighed into two pots and the samples were fertilized with 100 ppm nitrogen and 80 ppm phosphorus.

Large differences in yield were found among overburden and soil samples from all six sites. Yields ranged from 0.01 g to 4.65 g/pot. Relative yields were calculated as percentage of the yield of the standard soil (Platner series). Relative yields below 33% were considered low, between 33 and 67% medium, and above 67% high. The percentage of geologic and soil samples in each range were:

	Geologic	Soils
Low	26%	20%
Medium	52%	51%
High	22%	29%

Textures of the overburden ranged from very coarse to very fine, pH values ranged from 3.3 to 10.1, and electrical conductivities ranged up to 21 mmhos/cm.

ACKNOWLEDGEMENTS

The help of Gary Browning, CSU undergraduate, and Kathryn Beaumont, research technician, in carrying out the greenhouse work is greatly appreciated. The help of Lori Nukaya, secretary, in completing this report is also appreciated. Special thanks goes to the U.S. Bureau of Reclamation for funding the project and chemical and physical characterization of the overburden.

INTRODUCTION

In the past, surface mining for coal generally resulted in burying of the soil and then attempts were made to revegetate the spoil. The spoil left exposed was usually from the stratum directly overlying the coal seam and often was not a suitable plant growth medium.

It is visualized that in future surface mining operations, the soil will be conserved and replaced. However, on some sites the soil will be thin or less suitable as a plant growth medium than spoil generated from certain overburden strata. The objective of this study was to evaluate the suitability of overburden as plant growth media.

This greenhouse study was a portion of a larger study carried out by the Bureau of Reclamation in coring and characterizing overburden on potential federal coal lease sites. This report is on the Bear Creek, Horse Nose Butte, Red Rim, Bisti West, Foidel Creek, and White Tail Butte EMRIA sites. A previous report was on the Alton, Hanna Basin, Otter Creek, and Taylor Creek EMRIA sites.

METHODS

Field Capacity

The initial task in the greenhouse study was to determine the field capacity of the overburden samples. The equipment used to determine field capacity was: plastic tubes 1 3/4 inches in diameter, plastic cups, and plastic sheets. Four hundred grams of each overburden sample was weighed and placed in the plastic cylinders which had been sealed at the bottom by a plastic sheet, and packed by tapping the side of the cylinder. Twenty milliliters of water was then added (5% of the overburden by weight) and the top was sealed with a plastic sheet. After 24 hours, the bottom plastic sheet was removed and the dry overburden fell into the plastic cup, leaving the moist overburden in the cylinder. The dry overburden was weighed and the field capacity (FC) calculated by the following equation:

$$FC = \frac{20 \text{ g } H_2O}{400 \text{ g - Weight of dry overburden}} \times 100$$

The field capacity percentage was the basis for the amount of water each pot received daily.

Fertilizer Treatments

Two thousand grams of each overburden and soil sample were weighed into each of two pots. Each pot was fertilized with 100 ppm of nitrogen as reagent grade $Ca(NO_3)_2$ and 80 ppm phosphorus as reagent grade $Ca(H_2PO_4)_2 \cdot H_2O$. The reagents were added in solution as 10 and 50 ml aliquots respectively, then mixed into the soils and overburden. Where sufficient soil material was not available for a

2 kg sample weights, the aliquot sizes were adjusted to maintain a fertility level of 100 ppm N and 80 ppm P.

Seeding and Growth

Western wheatgrass (*Agropyron smithii* var. Arriba) was the test species. This species was chosen because it is one of the most abundant native grasses in the Western United States and will probably be used in many revegetation programs.

At the time of seeding, approximately 250 g of overburden was removed from each pot. Then water was added to each pot to bring them to field capacity. Forty seeds were placed in each pot and the previously removed dry overburden placed on the seeds. All pots were then covered with paper to retard evaporation and to allow the water to move to the surface by capillary rise. The pots were checked daily and upon germination, each pot was uncovered and the date recorded. The date when ten plants had emerged and the severity of salt crusting were also recorded. After germination, all pots were weighed daily and deionized water was added to bring the soil to field capacity. Maximum water use was approximately 25% of field capacity per day.

When the majority of the plants, in all pots, reached a height of 10 cm, the number of plants in each pot was recorded and each pot was thinned to 16 plants.

Two highly productive loam soils were included in each experiment as overall standards (A_1 horizon Platner series and A_1 horizon Kimm series). In Table B-4a greenhouse data on the standard soils is included at the end of the table.

Plants were harvested at approximately the same growth stage on all experiments. Because of growing conditions, the growth period varies for each experiment. Western wheatgrass was grown for 62 days following seeding, on the overburden from the Bear Creek site, Montana (September 28 to November 29, 1975), for 56 days on the samples from the Horse Nose Butte site, North Dakota and the Red Rim site, Wyoming (January 17 to March 13, 1976), for 49 days on the overburden from the Bisit West, New Mexico and Foidel Creek, Colorado sites (April 10 to May 29, 1976), and for 59 days on the overburden samples from the White Tail Butte site, Wyoming (September 16 to November 14, 1976).

Harvesting

The plants were clipped at a height of 2 cm above the soil surface to minimize contamination by soil splashed on the plants during watering. The harvested plants were then washed in 0.05 normal HCl and rinsed in distilled water so tissue analysis could be done on the plant samples. The plants were dried in a forced air oven at 70° C for 24 hours and then weighed to the nearest 0.01 gram.

Observations taken at the time of harvest included (1) the presence of shoot growth from rhizomes; (2) the degree of soil surface cracking; (3) the amount of salt crusting; and (4) the average plant height.

In comparing average plant height and plant dry weight it can be seen that there is no direct correlation. These differences are believed to be partially due to variation in light response in different seasons. Also, within experiments, a portion of the variation appears to be related to the amount of shoot growth originating from rhizomes, in that overburden samples with a low yield and tall average plant

height generally had very little or no growth from rhizomes while those samples with a high plant yield and a lower average plant height generally had a relatively large amount of growth from rhizomes. Also, the clayier samples generally had the largest amount of growth from rhizomes.

RESULTS

Large differences in Western wheatgrass growth are evident on various overburden samples (Figure B-9). Because there was a wide range on plant dry weights from the standard soils in the four greenhouse experiments, relative yields will be used in this discussion. Actual and relative yields are presented in Table B-4a. Relative yield was calculated as a percentage of yield of the Platner standard soil from the respective greenhouse experiments. For purposes of this discussion relative yields less than 33% will be considered low, 33-67% medium, and above 67% high.

Figure B-9 Range in Western wheatgrass growth on overburden and soil samples from the Bisti West site.

Bisti West, New Mexico (Kirtland, Fruitland, & Pictured Cliffs formations)

Geologic samples from the Bisti West, New Mexico site generally yielded low to medium. Fifty-one percent of the samples yielded low, 47% medium, and one sample or 2% yielded high (Figures B-10 and B-11, table B-4a). These overburden samples were generally sodic with a few being saline-sodic. These samples with a high sodium content were mostly fine-textured with swelling clays resulting in a large amount of surface cracking. Also, these samples had high pH values with 87% of the samples having a pH of 9.0 or greater and 20% with a pH of 10.0 or 10.1. The majority of the geologic samples from this site have physical and chemical characteristics which make them unsuitable as plant growth media.

Soil samples from the Bisti West site yielded much better than the geologic samples. Relative yields were 10% low, 58% medium, and 23% high (Figure B-12, Table B-4a). The soil samples have better characteristics as plant growth media but some have sodium problems. In general, the surface soils showed the most favorable characteristics and generally yielded more than subsurface samples.

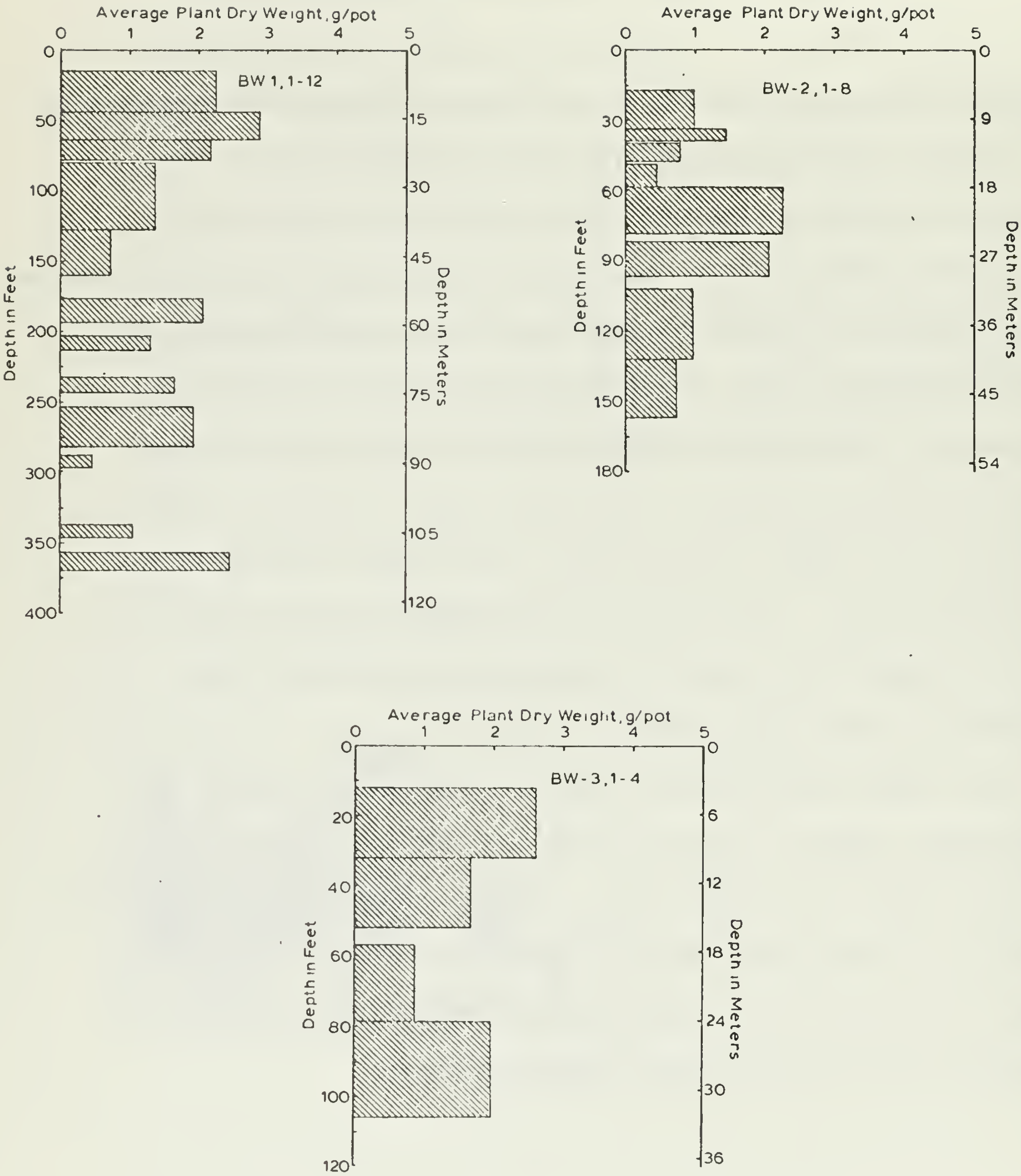
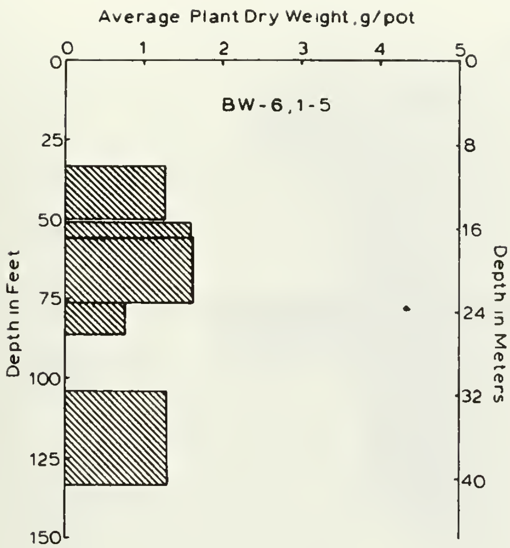


Figure B-10 Yields of western wheatgrass on overburden samples from coreholes DH-1, DH-2, and DH-3, Bisti West site in New Mexico.



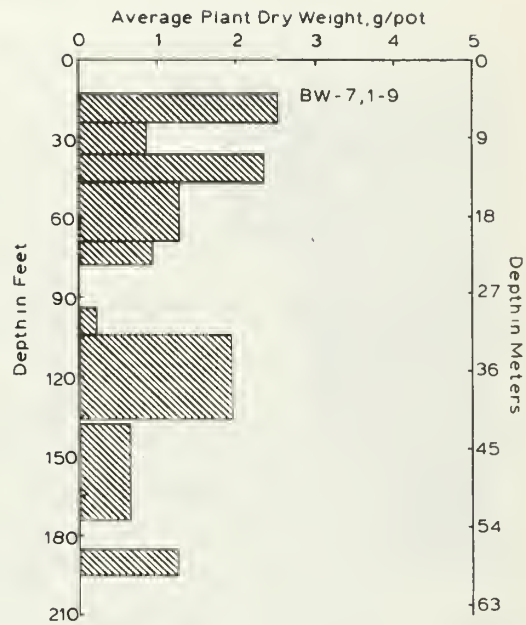


Figure B-11 Yields of western wheatgrass on overburden samples from coreholes DH-6 and DH-7, Bisti West site in New Mexico.

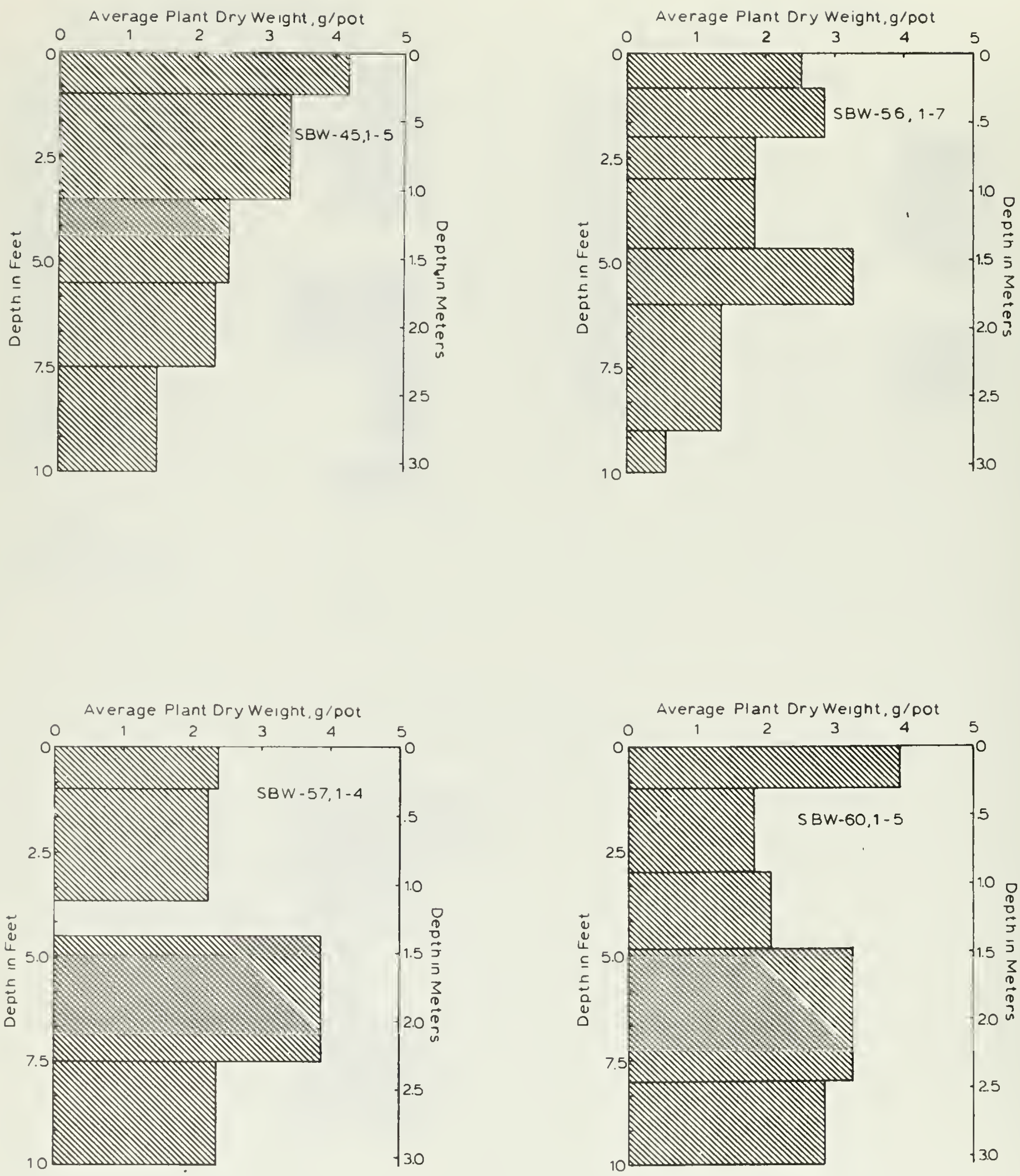


Figure B-12 Yields of western wheatgrass on soil profile samples from the Bisti West site in New Mexico.

DISCUSSION

Large differences in yield were noted among overburden and soil samples from all six sites. Those overburden samples which had relative yields less than 33% would definitely not be suitable as plant growth media. The samples with relative yields larger than 33% include some strata which would make a favorable plant growth media, but also include some strata which would make unsuitable plant growth media under field conditions.

In the greenhouse study, overburden samples with the higher field capacities generally yielded the most. In the field, under arid and semi-arid conditions, these fine-textured materials would be the more drouthy soils becasue of greater surface runoff and evaporation. Thus, growth differences reported in this greenhouse study will give only an indication of the overburden suitability as a plant growth media. When extrapolating greenhouse results to field conditions, the physical and chemical characteristics of the overburden must be analyzed along with the greenhouse yield data to make interpretations on the suitability of the strata as a plant growth media.

Multiple regression analyses were run in an attempt to correlate yield with chemical and physical charateristics. For samples from one site, significant correlations were found but no significant correlations were found where all sites were included. This data will be included in a thesis on "Characterization of Overburden as a Plant Growth Media".

GREENHOUSE YIELDS AND OBSERVATIONS

The degree of surface cracking of the overburden were given a numerical designation as follows:

0 - none
1 - very slight
2 - slight
3 - moderate
4 - extreme

The degree of salt crusting was also observed and recorded as follows:

0 - no salt crust present
1 - 1-30% of surface area covered with salt crust
2 - 31-60% of surface area covered with salt crust
3 - 61-90% of surface area covered with salt crust
4 - 91-100% of surface area covered with salt crust

Blackened leaf tips were observed and frequency of occurrence, within pots, was recorded as follows:

0 - no plants with black leaf tips
1 - 1-4 plants with black leaf tips
2 - 5-8 plants with black leaf tips
3 - 9-12 plants with black leaf tips
4 - 13-16 plants with black leaf tips

These blackened leaf tips (5-10 mm) changed to a brown color after 1-2 weeks. Although the leaf tips died back, there was no evidence of overall yield reduction of plants so affected.

Roman numerals I and II in the following tables refer to replications. Duplicate pots were run on all soil and overburden samples for which there was adequate soil material.

Table B-4a Bisti West Greenhouse Data.

Drill hole (D.H.) no. Sample no.			Germination						Harvest							
			Days After Seeding for Ten Plants to Emerge		Number of Seeds Germinated				Plant Dry Weight (gm)			Average Plant Height (cm)				
Sample No.	Depth (ft)	Pot Wt. (Kg)	I	II	I	II	Salt Crust at Germination	Salt Crust at Harvest	I	II	Relative Yield (%)	I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
BW- 1- 1	15.0 - 44.0	2	8	14	39	17	1	0	2.92	1.51	53	33	26	0	2	21.87
BW- 1- 2	44.0 - 63.0	2	7	7	33	34	1	1	2.92	2.86	70	33	34	2	3	23.27
BW- 1- 3	63.0 - 77.0	2	7	*	33	*	1	1	2.19	*	52	31	*	0	3	54.47
BW- 1- 4	78.0 - 128.0	2	8	8	33	37	1	0	1.20	1.54	33	24	26	1	2	20.90
BW- 1- 5	128.0 - 160.0	2	11	10	21	33	1	0	0.83	0.60	17	20	14	0	2	18.15
BW- 1- 6	176.0 - 193.0	2	8	7	33	34	2	0	1.90	2.28	50	33	34	0	1	52.32
BW- 1- 7	203.0 - 212.0	2	8	8	30	27	1	2	1.28	1.32	31	27	27	0	3	25.46
BW- 1- 8	232.0 - 242.0	2	8	8	28	28	1	2	2.12	1.22	40	32	29	0	4	27.51
BW- 1- 9	253.0 - 282.0	1.85	9	9	36	20	1	2	1.52	2.32	46	26	34	1	4	24.27
BW- 1-10	287.6 - 296.0	2	11	10	18	33	1	1	0.52	0.46	12	20	21	0	1	15.53
BW- 1-11	338.0 - 346.0	2	9	8	21	31	1	1	0.89	1.19	25	24	24	0	4	29.96
BW- 1-12	357.0 - 370.0	2	7	8	35	34	1	0	2.51	1.98	54	32	30	0	0	18.30
BW- 2- 1	17.2 - 33.7	1.7	9	*	37	*	1	1	0.99	*	24	25	*	0	3	18.45
BW- 2- 2	33.7 - 38.4	2	8	8	27	36	3	2	1.44	1.43	34	25	27	1	3	17.37
BW- 2- 3	39.6 - 47.7	2	10	10	30	29	1	2	1.00	0.60	19	20	15	0	3	17.57
BW- 2- 4	48.9 - 58.6	2	10	10	34	30	1	1	0.70	0.24	11	19	18	0	2	17.68
BW- 2- 5	58.6 - 78.5	2	8	8	34	33	2	1	2.18	2.34	54	30	34	0	2	55.13
BW- 2- 6	82.0 - 96.5	2	8	8	37	35	1	0	1.90	2.22	49	29	33	0	1	57.84
BW- 2- 7	102.0 - 132.0	2	7	8	26	22	1	0	1.18	0.79	24	26	21	0	4	26.78

* Sample enough for only one pot.

Table B-4a (cont.) Bisti West Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
BW- 2- 8	132.0 - 157.0	2	8	9	31	30	1	1	0.79	0.69	18	19	15	0	4	19.81
BW- 3- 1	12.0 - 32.0	2	8	*	32	*	2	1	2.60	*	62	29	*	1	1	30.98
BW- 3- 2	32.0 - 52.0	2	9	8	27	26	2	2	1.73	1.46	38	26	30	0	4	29.48
BW- 3- 3	57.0 - 79.0	2	9	8	25	33	1	1	0.56	1.19	21	13	28	1	4	20.10
BW- 3- 4	79.0 - 106.0	2	7	7	27	25	1	0	2.00	1.96	47	30	15	0	4	25.69
BW- 4- 1	28.0 - 69.0	2	6	8	32	30	1	1	0.60	0.82	17	21	19	0	4	19.28
BW- 4- 2	71.0 - 104.8	2	7	10	36	31	2	0	2.91	2.21	61	33	31	1	0	29.14
BW- 5- 1	22.0 - 37.0	2	10	10	29	22	2	4	1.47	0.92	29	26	19	1	4	34.20
BW- 5- 2	37.0 - 57.0	2	8	8	34	33	2	3	0.53	0.49	12	19	12	0	4	25.47
BW- 5- 3	64.0 - 74.8	2	8	8	32	31	1	1	0.73	0.30	12	16	13	0	4	28.95
BW- 5- 4																
Sandstone	81.0 - 101.5	2	7	9	32	30	1	2	1.80	1.39	38	29	30	0	2	22.55
BW- 5- 4																
Shale	81.0 - 101.5	2	7	8	33	26	1	1	1.41	0.49	23	29	23	0	4	37.64
BW- 6- 1	33.0 - 50.0	2	9	13	20	17	1	1	0.87	0.40	15	17	17	0	4	20.47
BW- 6- 2	51.0 - 56.0	2	11	8	19	36	1	1	1.28	1.91	38	28	29	0	2	49.75

* Sample enough for only one pot.

Table B-4a (cont.) Bisti West Greenhouse Data.

Sample No.	Depth(ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
BW- 6- 3	56.0 - 76.0	2	8	8	33	33	1	2	1.51	1.71	38	26	29	0	4	25.54
BW- 6- 4	76.0 - 86.0	2	8	8	31	28	1	1	0.84	0.68	18	19	22	0	4	39.53
BW- 6- 5	104.0 - 133.0	2	9	9	30	28	1	0	1.39	1.17	31	24	24	1	1	76.92
BW- 7- 1	13.0 - 24.0	2	7	16	35	16	3	1	2.92	2.14	60	34	30	2	2	60.98
BW- 7- 2	24.0 - 36.0	1.8	9	8	19	38	1	2	0.59	1.16	21	18	27	0	3	20.79
BW- 7- 3	36.0 - 47.0	2	8	7	35	37	2	0	2.06	2.60	56	30	32	0	2	33.96
BW- 7- 4	47.0 - 69.0	2	7	8	35	36	2	2	1.44	1.07	30	28	25	0	2	53.46
BW- 7- 5	69.0 - 78.0	2	8	8	34	28	2	1	1.03	0.79	22	20	21	0	3	21.19
BW- 7- 6	94.0 - 104.0	2	10	11	24	28	1	1	0.38	0.04	5	14	10	0	2	18.17
BW- 7- 7	104.0 - 136.0	2	7	7	30	32	2	0	1.83	2.03	46	30	29	0	0	53.05
BW- 7- 8	138.0 - 174.0	2	9	8	38	30	1	1	0.40	0.90	16	17	23	1	4	23.20
BW- 7- 9	185.0 - 195.0	2	8	10	21	23	1	2	1.87	0.67	30	25	22	0	4	20.73

Table B-4a (cont.) Bisti West Greenhouse Data.

Auger hole/profile no. Sample no.			Germination						Harvest							
			Days After Seeding for Ten Plants to Emerge		Number of Seeds Germinated				Plant Dry Weight (gm)			Average Plant Height (cm)				
Sample No.	Depth(in)	Pot Wt. (Kg)	I	II	I	II	Salt Crust at Germination	Salt Crust at Harvest	I	II	Relative Yield (%)	I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
SBW- 1- 1	0.0 - 48.0	2	7	7	27	26	0	0	2.51	2.83	64	31	36	1	0	10.18
SBW- 1- 2	48.0 - 72.0	2	24	21	24	25	0	0	0.67	0.71	16	21	20	0	0	9.12
SBW- 1- 3	72.0 - 132.0	2	7	7	21	20	0	0	0.64	0.79	17	22	21	1	0	6.91
SBW- 1- 4	132.0 - 180.0	2	7	8	33	32	0	0	1.03	1.12	26	26	26	1	0	7.09
SBW- 4- 1	0.0 - 24.0	2	10	*	28	*	0	0	2.16	*	52	27	*	0	3	15.70
SBW- 4- 3	84.0 - 120.0	2	9	11	27	28	2	4	0.71	0.63	16	20	20	0	0	21.40
SBW- 4- 4	120.0 - 144.0	2	37	43	18	18	0	0	0.42	0.23	8	8	8	0	2	43.25
SBW-14- 1	0.0 - 12.0	2	7	7	39	38	0	0	2.92	2.34	63	32	34	1	0	8.00
SBW-14- 2	12.0 - 48.0	2	7	7	36	34	0	1	2.48	2.18	56	35	33	1	0	9.46
SBW-14- 3	48.0 - 84.0	2	7	7	34	33	0	0	2.72	2.06	57	32	31	0	0	14.12
SBW-14- 4	84.0 - 120.0	2	7	8	33	36	0	0	1.53	1.43	35	28	30	1	0	11.83
SBW-40- 1	0.0 - 12.0	2	10	7	21	37	2	1	1.06	1.98	36	22	30	2	0	18.69
SBW-40- 2	36.0 - 60.0	2	7	*	26	*	1	1	2.14	*	51	29	*	1	3	18.37
SBW-41- 1	0.0 - 12.0	2	8	7	36	38	0	0	3.21	2.05	63	34	31	0	0	10.87
SBW-41- 2	12.0 - 40.0	2	8	8	37	36	1	1	1.94	1.30	39	32	27	1	0	12.41
SBW-41- 4	48.0 - 108.0	2	11	11	20	16	1	4	0.43	0.54	12	17	14	0	0	22.22

* Sample enough for only one pot.

Table B-4a (cont.) Bisti West Greenhouse Data.

Sample No.	Depth (in)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
SBW-57- 1	0.0 - 12.0	2	7	7	38	37	1	1	2.66	2.13	57	32	32	1	1	19.65
SBW-57- 2	12.0 - 44.0	2	7	7	35	37	1	0	2.48	1.97	53	34	31	0	0	13.01
SBW-57- 3	54.0 - 90.0	2	8	7	38	39	0	1	4.13	3.63	93	37	37	0	0	24.27
SBW-57- 4	90.0 - 120.0	2	7	20	35	16	1	2	3.55	1.16	56	35	29	1	2	25.19
SBW-60- 1	.0 - 12.0	2	6	6	39	38	0	0	3.88	3.97	94	38	41	1	0	15.30
SBW-60- 2	12.0 - 36.0	2	7	9	23	28	2	2	2.14	1.50	43	30	28	0	2	19.05
SBW-60- 3	36.0 - 58.0	2	8	7	31	27	1	0	2.10	2.05	50	30	31	0	4	21.60
SBW-60- 4	58.0 - 96.0	2	7	9	30	34	2	2	3.35	3.07	77	34	34	1	3	21.44
SBW-60- 5	96.0 - 120.0	1.95	7	8	34	31	2	2	3.17	2.47	67	35	30	0	3	22.24
SBW-63- 6	108.0 - 132.0	1.95	8	8	30	35	1	1	2.25	1.81	49	30	30	1	2	20.62
SBW-64- 1	0.0 - 6.0	2	7	7	34	34	1	1	2.47	2.06	54	31	31	1	1	18.20

Table B-4a (cont.) Bisti West Greenhouse Data.

Sample No.	Depth (in)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	Germination: Days After Seeding for Ten Plants to Emerge II	Germination: Number of Seeds Germinated I	Germination: Number of Seeds Germinated II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	Harvest: Plant Dry Weight (gm) II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	Harvest: Average Plant Height (cm) II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
SBW-43- 1	0.0 - 12.0	2	7	8	36	38	1	0	3.04	2.80	70	34	33	1	1	18.71
SBW-43- 3	22.0 - 42.0	1.9	8	7	26	29	1	1	2.40	2.61	60	30	34	1	3	18.67
SBW-43- 4	42.0 - 78.0	1.8	8	8	36	33	1	0	2.65	2.35	60	33	32	1	0	13.70
SBW-43- 5	78.0 - 120.0	2	7	8	39	36	1	0	2.70	3.70	76	33	30	2	0	12.29
SBW-45- 1	0.0 - 12.0	2	6	6	38	38	0	0	4.00	4.39	100	38	39	1	0	12.72
SBW-45- 2	12.0 - 42.0	1.95	7	8	36	36	0	0	3.48	3.17	79	36	37	1	0	16.30
SBW-45- 3	42.0 - 66.0	1.95	8	8	38	37	1	0	2.09	2.84	71	35	35	1	0	17.26
SBW-45- 4	66.0 - 90.0	2	7	8	37	33	0	0	2.54	2.01	54	32	33	2	0	17.68
SBW-45- 5	90.0 - 120.0	2	9	10	33	32	1	0	1.84	0.97	34	28	26	2	1	15.22
SBW-56- 1	0.0 - 10.0	2	8	B	35	30	1	1	2.62	2.41	60	32	34	1	1	22.38
SBW-56- 2	10.0 - 24.0	2	8	*	28	*	0	1	2.85	*	68	32	*	1	2	20.43
SBW-56- 3	24.0 - 36.0	2	8	*	33	*	2	0	1.85	*	44	30	*	3	1	19.44
SBW-56- 4	36.0 - 56.0	1.8	19	11	22	20	2	3	1.92	1.78	44	28	30	0	3	24.28
SBW-56- 5	56.0 - 72.0	2	6	*	35	*	1	1	3.27	*	78	33	*	1	2	30.61
SBW-56- 6	72.0 - 108.0	2	7	8	28	26	1	1	1.49	1.17	32	27	28	1	3	20.24
SBW-56- 7	108.0 - 120.0	2	12	*	16	*	1	1	0.57	*	14	18	*	1	2	21.31

*Sample enough for only one pot.

Table B-4a (cont) Bisti West Greenhouse Data

Sample No.	Depth	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
STANDARD SOILS																
Platner																
Check	surface	2	6	6	40	35	0	0	3.83	4.54	100	37	39	0	0	15.2
Kimm	surface	2	6	6	38	37	0	0	4.57	4.92	113	38	43	0	0	20.6
R-438-26																
Control	surface	2	7	7	37	36	0	0	2.03	1.54	43	29	30	0	0	13.14
Red Rim																
Check	surface	2	7	7	39	37	0	0	4.80	3.31	110	39	41	1	0	18.4

ADDITIONAL DATA

Blackening of the leaf tips was observed on various samples. This blackening of the leaf tips was hypothesized to be boron toxicity, but work done by Bureau of Reclamation personnel in Billings, Montana showed that there was no correlation between the amount of hot water soluble boron and the amount of blackened leaf tips. This blackening of leaf tips was also noted in a previous greenhouse study on overburden from the Alton, Hanna Basin, Otter Creek, and Taylor Creek EMRIA sites.

In some cases, sufficient soil material was not available for a sample weight of 2.0 kg (Table B-4a). It was not known whether significant yield decreases per pot would result if the sample weight was less than 2.0 kg so an experiment was conducted using three soils with five sample weights (2.0, 1.9, 1.8, 1.6, and 1.4 kg). The soils used were the Platner and Kimm standard soils and the C_{ca} horizon from the Kimm series which will be called Kimm C_{ca} in this report. All treatments were replicated 3 times, making a total of 45 pots. Western wheatgrass was grown on the soils for 56 days following seeding (January 17 to March 13, 1976). The samples were fertilized and seeded and the plants thinned and harvested following the previously mentioned procedures. An analysis of variance (AOV) was run on the data (Table B-4b) to determine if there were any significant differences in yields. The results showed that there were significant differences in yields between the sample weight (0.001 level). Since the AOV showed there were significant differences, a Duncans Multiple Range test was conducted.

These results showed that there were significant differences in yield at the 5% level between all sample weights except 2.0 versus 1.9 kg; 1.9 versus 1.6 kg; and 1.6 versus 1.4 kg. This shows that for statistical comparison purposes, a sample weight of 1.9 or 2.0 kg is needed for this study.

Table B-4b Yields of western wheatgrass as a function of weight of soil per pot.

Soil Sample	Pot Wt. (Kg.)	Plant Dry Weight I	Plant Dry Weight II	Plant Dry Weight III
Platner	2.0	2.89	2.79	2.35
Platner	1.9	2.34	2.65	2.65
Platner	1.8	2.47	2.61	2.56
Platner	1.6	2.16	2.56	2.00
Platner	1.4	2.67	2.32	2.40
Kimm A_1	2.0	4.85	4.56	4.39
Kimm A_1	1.9	4.29	4.34	4.33
Kimm A_1	1.8	3.65	4.52	4.16
Kimm A_1	1.6	4.46	3.55	3.73
Kimm A_1	1.4	3.64	3.31	3.51
Kimm C_{ca}	2.0	2.83	2.86	2.56
Kimm C_{ca}	1.9	2.97	3.00	3.22
Kimm C_{ca}	1.8	2.42	2.29	2.35
Kimm C_{ca}	1.6	2.19	2.87	2.98
Kimm C_{ca}	1.4	2.24	2.38	2.15

Pot Weight (Kg)	Mean Plant Dry Weight (g)
2.0 a*	3.34
1.9 a	3.31
1.8 b	3.00
1.6 b, c	2.94
1.4 c	2.74

* Any two pot weights followed by the same letter are not significantly different at the 0.05 level.

Soil samples from natural horizons and layers were tested in the laboratory. Tests in the following list were performed on soil samples as needed for proper evaluation. The results are shown

PSA - The procedure is a modification of the pipette method. The soil is not treated with hydrogen peroxide for destruction of organic matter, and is not washed for removal of salts (Kilmer and Alexander, 1949).

Moisture retention - Porous plates are used for moisture retention measurement of soils at all pressures (Richards, 1947 and 1949b and Richards and Weaver, 1944).

Disturbed hydraulic conductivity - Soils are tamped mechanically. City water is used for the test. The temperature of the water is maintained at about 85 degrees F. (Fireman, 1944).

Settling volume - The soil used for the 1:5 dilution measurements is used for this determination. Distilled water and 10 ml of 30% calcium chloride solution are used (U.S.B.R. Reclamation Instructions, 1967).

pH - Measured with Beckman Expandomatic pH meter.

Saturation extract - Samples are mixed by hand and extract removed with a Baroid filter press. No preservative added.

Calcium and Magnesium - Determined by EDTA titration.

Sodium and Potassium - Determined with Baird-Atomic Model KY3 flame photometer and Perkin-Elmer Model 306 atomic absorption spectrophotometer.

Carbonate, bicarbonate, chloride, and sulfate - All are based on U.S. Geological Survey procedures (Brown and others, 1970).

The carbonate end-point is taken as pH 8.2.

Chloride is determined by the Mohr method.

Sulfate is determined by the Thorin method using Bausch & Lomb spectrophotometer Spectronic 20.

Nitrate - Determined by phenoldisulfonic acid method and Bausch and Lomb spectrophotometer Spectronic 20 (U.S. Salinity Laboratory Staff, 1954).

Exchangeable sodium and potassium - Based on soluble cations in saturation extract and extractable cations extracted with neutral normal ammonium acetate and measured with Baird Atomic Model KY3 flame photometer and Perkin-Elmer Model 306 atomic absorption spectrophotometer (U.S. Salinity Laboratory Staff, 1954).

Same reference as above

Gypsum - The high moisture percentage is a 1:5 dilution (U.S. Salinity Laboratory Staff, 1954).

Gypsum requirement - Difference between Ca concentration of added gypsum solution and Ca+Mg Concentration in filtrate, as meq/liter, times 2 (U.S.Salinity Laboratory Staff, 1954).

Calcium carbonate equivalent - Back titration with 0.4N NaOH to neutralize 0.4N HCl remaining after boiling period. Two drops of phenolphthalien indicator are used (U.S. Salinity Laboratory Staff, 1954).

Organic carbon - The wet-combustion method of Walkley is used, and diphenylamine is the indicator (Walkley, 1947).

Cation Exchange Capacity - Determined by using 1.0N sodium acetate solution at pH 8.2 and 1.0N ammonium acetate at pH 7.0. Sodium determined by Perkin-Elmer Model 306 atomic absorption spectrophotometer.

Table B-5

Results of Laboratory Tests on Auger Hole/Profile Samples (Soil)

LM-813 (Rev. 12/76)
Interior-Reclamation
Lower Missouri Region

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

GPO 838-390/29

Lab Number	Auger Hole/Profile No. — Sample No. — Site Number	Depth Inches	Hydraulic Conductivity Ins./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract $ec \times 10^3$ @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract $ec \times 10^3$ @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Ca+Mg Me 100g	Sat %	Gyp Me 100g	Na Me/100g Total Na	Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	15 Bars
46	BW1-1-75	0-48	1.44	.47	8.6	7.5	20	3		.10											.6		9.2			4.8
47	2	48-72	.47	.47	8.7	7.6	20	3		.46											2.4		9.6			4.7
48	3	72-132	5.50	.86	9.4	7.7	15	3		.21											1.4		8.8			2.3
49	4	132-180	.96	.70	9.2	7.7	14	3		.17											1.4		9.4			2.5
50	BW3-1-75	30-36	5.98	.39	8.8	7.7	13	-		.05											.2		5.4			2.4
51	2	36-66	4.22	.45	8.8	6.9	16	3		.08											.2		12.2			4.4
52	3	66-84	2.60	.74	9.0	7.1	18	3		.32											1.6		14.0			4.9
53	4	84-144	5.81	1.14	9.3	7.3	13	1		.20											.8		4.2			1.7
54	BW4-1-75	0-24	-	-	8.9	7.6	58	1		.69											10.4		66.0			31.3
55	3	84-120	-	.012	6.8	4.2	130	-		.36				7.24	61.0	20.4	19		61.8			3.8	36.0	10.6		15.7
56	4	120-144	-	-	8.5	6.6	300	-		.57				5.20	55.5	6.6	31		73.6			2.3	19.6	11.8		12.6
57	BW5-1-75	0-24	0.014	-	8.9	6.8	37	2		.38												1.2	25.0			8.8
58	2	32-66	1.58	.77	7.9	6.8	39	1		2.22				10.0	74.0	27.2	20		29.5			2.2	16.0	13.9		5.5
59	3	66-114	-	-	9.3	6.8	600	-		1.25				6.2	61.5	12.7	24		100.0			9.9	37.0	26.6		15.7
60	BW6-1-75	0-12	-	-	8.2	6.8	55	2		2.56				7.0	72.0	4.1	50		73.2			2.1	48.0	4.5		19.8
61	2	12-28	-	-	8.2	6.8	60	1		1.46											7.2		57.0			20.6
62	3	28-36	0.14	.05	8.4	7.1	31	2		.74											2.6		19.6			6.9
63	4	36-48	-	-	9.1	7.5	80	2		.52											6.0		44.0			15.1
64	5	48-64	-	-	9.1	7.4	45	2		.36											3.4		28.0			8.6
65	6	64-90	-	-	8.9	7.5	65	2		.49											3.4		53.0			19.0
66	7	90-100	.001	.002	9.0	7.4	39	3		.21											2.2		28.0			8.6
67	8	100-120	-	-	9.0	7.5	100	1		.32											3.6		40.0			16.7
68	BW7-1-75	0-12	1.76	.53	8.5	7.4	14	2		.06											.2		12.0			4.1
69	2	12-34	.96	.81	8.7	7.3	16	3		.07											.4		13.6			4.6
70	3	34-48	.34	.42	9.1	7.6	19	3		.21											1.2		9.6			4.7
71	4	48-90	2.34	.70	8.5	6.6	16	3		.58				4.8	34.5	10.0	15		22.7			.22	6.8	3.2		2.1
72	5	90-108	4.08	1.27	9.2	7.4	14	1		.18				1.81	15.6	4.0	11		20.9			.47	5.4	8.7		1.1
73	BW8-1-75	0-6	-	-	9.3	7.8	42	2		.62											6.0		28.0			10.5
74	2	6-36	.02	.002	8.5	7.7	40	1		1.33				8.0	81.0	25.5	23		40.8			3.3	28.0	11.8		9.7
75	3	36-76	-	-	9.0	7.8	400	1		1.00											15.0		74.0			24.3
76	4	76-96	.27	.28	8.0	7.5	29	3		1.62											9.2		29.0			7.4
77	5	96-120	-	-	8.0	7.4	200	-		1.52				7.2	84.0	18.3	28		67.9			8.3	56.0	14.8		23.0
78	BW9-1-75	0-12	6.56	2.00	8.3	7.2	15	2		.06											.2		7.6			2.4
79	2	12-48	4.78	1.58	9.0	7.4	16	-		.08											.6		7.2			3.0
80	3	48-54	-	-	8.8	7.8	130	2		1.19				9.0	68.0	20.4	21		53.3			3.4	22.0	15.4		12.3
81	4	54-60	-	-	8.2	6.7	140	2		3.50											10.0		32.0			14.5
82	BW10-1-75	0-12	.012	-	8.8	7.2	28	3		1.06				9.2	90.0	23.5	26		31.3			3.2	18.0	17.7		6.8
83	2	12-24	-	-	8.1	7.3	55	2		3.26				10.4	66.0	24.3	19		46.9			14.9	55.0	27.0		20.0
84	BW11-1-75	0-12	-	-	9.3	7.6	130	2		.40											6.0	6.0	38.0			15.9
85	2	12-36	.02	.012	8.2	7.6	35	2		1.73				8.0	87.0	23.0	26		39.7			2.4	28.0	8.4		11.7
86	3	36-52	.02	-	8.2	7.7	22	2		1.20				8.6	56.0	4.5	37		27.7			5.5	17.0	32.1		5.7
87	4	52-60	-	-	9.4	8.4	550	1		.59				3.0	28.5	2.2	28		115.9			14.7	52.0	28.2		21.7
88	BW12-1-75	0-12	5.46	.54	8.5	7.2	15	-		.05											.2		5.2			2.6
89	2	12-36	6.28	.58	8.4	7.3	15	-		.05											.2		7.0			2.7
90	3	36-60	-	-	9.5	7.7	100	2		.42				2.4	21.6	1.6	25		32.9			2.7	10.0	26.9		5.1
91	4	60-82	.40	.39	8.3	7.1	26	2		1.35											3.0		15.0			4.8
92	5	82-102	-	-	8.9	7.6	340	-		.93				8.8	87.0	16.2	31		93.5			10.9	50.0	21.7		19.0
93	BW14-1-75	0-12	4.40	1.00	8.5	7.0	13	1		.05											.2		5.4			1.8
94	2	12-48	4.06	1.80	8.7	7.2	15	3		.76											.2		7.4			2.0
95	3	48-84	-	-	9.5	7.4	42	3		.28				1.4	12.6				28.9			1.6	8.0	20.5		2.4
96	4	84-120	-	-	9.5	7.6	44	3		.32											1.4		6.4			2.3
97	BW15-1-75	0-12	4.14	1.08	9.0	7.7	15	3		.11											.4		8.0			2.6
98	2	12-48	-	-	9.6	7.9	46	3		.42				3.0	30.0	2.5	27		34.8			1.4	6.0	22.7		2.8
99	3	48-64	-	-	9.4	7.6	90	3		.79				6.0	64.5	9.8	29		33.2			1.7	14.0	11.9		5.3
100	4	64-72	-	-	9.7	8.0	60	3		.39				1.6	14.4	1.3	18		27.7			3.0				2.8
101	5	72-80	-	-	9.4	6.8	55	3		.52				7.6	69.0	22.8	20		67.0			1.0	12.0	8.5		4.1
102	6	80-90	-	-	8.9	7.1	140	1		.20				5.6	63.0	10.6	27		108.9			1.3	24.0	5.6		8.6
103	BW16-1-75	0-12	-	-	9.2	7.5	370	2		.19				5.8	55.5	7.0	30		29.7			12.2	48.0	25.3		20.4
104	2	12-30	-	-	9.0	7.6	508	1		.89				5.2	52.5	11.4	22		126.4			1.8				25.7
105	3	30-46	-	.004	8.7	7.6	49	3		.74				6.6	66.0	19.4	21		38.6			1.3	24.0	5.2		8.2
106	4	46-58	-	-	8.3	7.5	100	3		1.62				7.0	72.0	21.6	22		85.5			3.8	51.6	7.4		22.0
107	5	58-84	-	-	9.5	7.7	105	3		.33				1.69	16.8	.8	26		37.1			2.4	13.6	17.5		5.4
108	6	84-114	-	-	9.6	7.6	55	3		.30				1.4	13.5	1.3	17		31.5			0.97	4.4	22.0		3.3
109	BW17-1-75	0-12	5.06	1.82	8.8	7.4	14	1		.06												.2	9.6			2.6

Table B-5 (con.)

Results of Laboratory Tests on Auger Hole/Profile Samples (Soil)

LM-813 (Rev. 12/76)
Interior-Reclamation
Lower Missouri Region

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

GPO 838-360/29

Lab Number	Site Number	Depth Inches	Hydraulic Conductivity In./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract $ecx10^3$ @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract $ecx10^3$ @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Ca+Mg Me 100g	Sat %	Gyp Me 100g	Na Me/100g Total Na	Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	15 Bars
110	BW17-2-75	12-36	8.90	1.08	9.0	7.5	17	3		.11											.4		12.0			2.4
111	3	36-84	.13	.29	9.4	6.7	31	2		.24											2.0		8.0			2.2
112	4	84-138	-	-	9.5	7.0	44	2		.30											2.6		8.0			2.5
113	5	138-162	.06	.05	8.8	7.3	55	3		1.15				8.0	76.5	18.0	25		36.5			3.1				7.5
114	BW18-1-75	0-12	-	-	9.2	7.5	150	3		.49				2.8	27.0	5.2	17		53.2			5.8				12.3
115	2	18-42	-	-	9.0	7.5	60	3		.53																7.2
116	3	42-64	-	-	9.6	7.9	500	2		.35				1.6	16.5	1.8	17		85.2			6.6				20.2
117	4	64-86	.80	.48	8.5	7.5	23	3		.94											4.0					4.0
118	5	86-96	-	.001	8.3	7.6	65	2		2.07				9.0	90.0	28.6	24		66.9			7.0	26.0	26.8		16.4
119	BW19-1-75	0-12	-	-	9.2	7.7	170	2		.29											3.6					13.0
120	2	18-38	-	-	8.9	7.8	490	2		.66				3.4	33.0	5.6	20		124.3			8.9	32.0	27.8		24.1
121	3	38-80	.24	.30	8.9	7.0	34	3		.56											3.8		10.0			4.1
122	4	80-102	-	-	9.7	7.3	175	1		.32											4.0					3.1
123	5	102-120	-	.006	8.7	7.4	195	-		1.73				11.0	80.0	21.3	25		83.1			17.4				22.0
124	BW20-1-75	0-12	6.62	1.50	8.4	7.1	15	1		.06											.2		13.0			2.3
125	2	12-48	8.21	.75	8.4	7.2	16	2		.07											.2		8.6			2.5
126	3	48-84	8.80	.66	8.9	7.3	20	3		.13											.8		5.6			2.6
127	4	84-120	.04	.11	9.4	7.4	36	2		.25											1.8					2.5
128	BW21-1-75	0-12	-	-	8.5	7.7	52	2		.97											1.6		32.6			11.3
129	2	14-	-	-	8.4	7.8	200	-		1.07				6.0	60.0	8.4	29		91.9			13.5	56.0	24.0		21.2
130	BW22-1-75	0-12	-	-	7.8	7.6	65	3		2.14				12.0	80.0	28.2	21		65.5			16.8	52.0	32.2		21.4
131	2	12-24	.07	.07	6.4	5.0	200	-		2.71				12.6	88.0	27.1	24		60.0			14.7	42.0	35.0		19.4
132	3	24-36	-	-	7.6	6.6	43	-		.74				5.6	57.0	5.0	36		89.8			16.9				33.6
133	BW23-1-75	0-12	8.00	1.98	7.9	6.2	13	1		.06											.2		7.6			2.4
134	2	12-48	.04	.03	9.4	6.9	31	2		.23											1.8		7.6			2.6
135	3	48-84	.03	.01	9.4	7.1	33	2		.29											0.2		14.8			2.2
136	4	84-108	-	-	9.5	7.5	65	3		.40											3.8					3.8
137	5	108-120	-	-	8.1	7.6	300	-		1.55				7.4	69.0	25.6	19		130.5			9.8	27.6	28.0		13.2
138	BW24-1-75	0-12	4.22	1.4	8.5	7.5	13	1		.06											.1		7.8			2.6
139	2	12-48	4.64	1.5	8.8	7.4	15	2		.07											.3		7.8			2.6
140	3	48-96	-	-	9.6	7.6	42	3		.29				1.7	14.7	1.8	16		32.9			2.1	8.4	25.2		2.4
141	4	96-120	-	-	9.7	6.7	39	1		.30				2.4	22.5	2.1	22		28.3			1.96				2.6
142	BW25-1-75	0-12	.38	.33	8.5	7.3	29	1		1.44				8.6	82.5	23.3	24		34.5			3.15	16.4	19.2		5.7
143	2	12-24	.04	.002	8.8	7.5	38	-		1.05				9.2	76.0	23.4	22		31.3			4.0				4.5
144	3	24-66	-	-	9.5	7.6	38	1		.46											3.2		13.0			3.0
145	4	66-90	-	-	9.4	7.7	70	3		.62				7.2	69.0	15.4	25		30.6			0.69	7.4	9.3		3.5
146	5	90-120	-	.008	8.3	7.7	70	3		.48				6.6	64.0	28.6	17		47.4			6.9	31.0	22.5		11.5
147	BW27-1-75	0-12	.24	.30	8.2	7.8	31	2		.28											7.0		22.0			7.9
148	2	12-36	.11	.03	8.4	7.7	29	1		2.17				10.6	63.0	31.7	16		32.4			1.11	14.0	8.2		5.8
149	3	36-50	.12	.02	8.6	7.7	26	1		1.36											1.4					2.8
150	4	50-70	-	-	8.8	7.7	46	1		.26											3.2					3.2
151	5	70-78	-	-	9.3	7.1	95	3		2.71											4.0		19.0			6.6
152	BW29-1-75	0-12	.64	.63	8.3	7.2	23	1		3.62				7.4	64.5	28.0	17		30.7			2.4	15.0	16.1		5.6
153	2	12-46	.36	.32	8.7	7.3	24	1		2.17				6.4	51.0	23.0	15		32.9			0.72	12.2	5.9		4.2
154	3	46-64	-	-	9.2	7.5	50	1		1.94											3.0		14.0			4.2
155	4	64-102	.004	.004	9.6	7.7	50	3		.84											3.8		12.0			3.5
156	BW30-1-75	0-12	.06	.006	8.7	7.7	25	2		.60				7.58	78.0	22.7	23		29.1			0.53	12.0	4.4		5.8
157	2	12-24	-	.001	8.5	7.7	42	2		.55											3.6		22.0			13.4
158	3	24-64	-	-	8.2	7.6	54	2		.72											9.8		51.0			17.5
159	4	64-84	-	.02	8.0	7.6	41	2		1.75				10.96	116.0	30.9	30		47.5			6.49	50.0	13.0		14.0
160	5	84-96	-	-	8.0	7.7	65			.54				10.90	112.0	28.9	29		61.2			8.15	37.0	22.0		21.6
161	BW31-1-75	0-12	-	-	9.5	6.9	41			.53											1.0		10.2			5.7
162	2	12-24	.22	.28	8.4	7.1	24			.48											6.4		21.0			5.6
163	3	24-24	.12	.17	8.2	7.3	40			.78				11.0	120.0	25.0	34		34.1			3.91	28.0	14.0		7.3
164	4	44-120	-	-	9.5	7.4	43							2.60	29.0	3.4	21		32.7			1.72	15.0	11.5		4.7
165	BW32-1-75	0-12	-	-	9.1	7.6	52			2.71				4.67	42.0	10.8	18		38.4			0.19	21.0	1.0		10.1
166	2	12-24	-	-	7.2	7.6	70			.88				5.40	52.5	17.8	18		62.9			4.1	43.0	9.5		17.3
167	3	24-60	.12	.10	7.0	7.7	33			1.40					73.5	24.0	21		39.1			2.73	32.0	8.5		9.9
168	4	60-84	-	-	7.9	7.8	350			.76				5.14	52.5	10.4	23		113.6			6.44	68.0	9.5		25.3
169	5	84-102	.24	-	8.0	7.6	32			.62											2.8		14.0			4.7
170	6	102-120	-	-	7.2	7.3	95			1.89				7.68	79.5	22.2	24		63.3			6.97	44.0	15.8		21.2
171	BW33-1-75	0-12	.04	.05	7.5	7.0	28			2.71				8.94	92.0	25.0	26		40.2			5.90	32.0	18.4		12.0
172	2	12-48	-	-	8.2	7.3	38			.92				7.10	70.5	21.0	22		40.3			3.96	20.0	19.8		9.9
173	3	48-66	.05	-	8.6	7.2	37			.37											3.4		17.0			5.1
174	4	66-84												8.50	87.0	26.2	24		56.4			6.69	40.0	16.7		19.9

LM-813 (Rev. 12/76)
Interior-Reclamation
Lower Missouri Region

Table B-5 (con.)

Results of Laboratory Tests on Auger Hole/Profile Samples (Soil)

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

GPO 838-360/29

Lab Number	Site Number	Depth Inches	Hydraulic Conductivity Ins./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract $ecx10^3$ @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract $ecx10^3$ @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	15 Bars
175	Surface																				2.2		21.0			9.8
176	BW34-1-75	0-12	.22	.12	8.5	7.6	26			.72				6.80	58.5	24.9	17	35.7				1.51	23.0	6.6		20.4
177	2	12-36	.05	.002	8.1	7.7	35			.46											2.6		20.4			7.1
178	3	36-72	.02	-	8.5	7.7	50			.83				6.86	53.2	24.0	15	47.8				2.7	25.6	10.4		9.7
179	4	72-84	-	-	9.1	7.6	65	1		.32											3.0		27.0			10.1
180	BW35-1-75	0-12	.17	.36	7.9	7.6	32	2		2.84				10.5	108.0	28.5	29	43.7				4.88	23.6	20.7		7.2
181	2	12-24	.05	.07	7.8	6.8	35	1		3.01				9.64	104.0	27.7	28	45.8				3.64	30.0	12.1		12.4
182	3	24-48	.04	.01	8.0	7.2	41	1		1.81				9.30	94.0	28.2	25	46.8				4.2	27.6	15.2		11.4
183	4	48-84	.63	.64	7.9	7.3	22	-		1.09				6.88	70.5	23.6	21	26.3				1.75	14.6	12.0		4.5
184	5	84-120	.62	1.08	8.1	7.3	25	2		.84											3.4		18.0			5.3
185	BW36-1-75	0-12	.05	.02	7.9	7.4	31	2		1.81				11.0	114.0	30.2	29	45.2				1.45	28.0	5.2		10.4
186	2	12-30	.06	.02	7.8	7.6	31	2		1.47				8.5	90.0	25.9	25	40.6				3.55	25.8	13.8		10.2
187	3	30-60	-	-	9.2	7.8	100	-		.39											4.2		20.0			8.5
188	4	60-84	-	-	9.1	7.9	100	3		.54											6.6		29.0			13.1
189	5	84-120	.39	.42	8.4	7.7	26	3		.94											3.2		15.2			6.0
190	BW37-1-75	0-12	.05	.07	8.0	7.7	42	1		3.01				8.1	94.0	24.5	27	51.6				1.15	29.0	4.0		14.7
191	2	12-30	-	.008	8.0	6.8	45	1		3.03				9.0	94.0	25.8	26	58.2				1.93	37.6	5.1		16.4
192	3	30-72	-	-	8.9	7.4	60	2		.80											4.4		18.6			7.8
193	4	72-96	.08	.11	7.9	7.5	45	3		2.10											7.0		37.0			12.1
194	BW38-1-75	0-12	-	-	8.3	7.6	55	3		1.38				6.94	70.5	23.6	21	48.8				3.16	29.6	10.7		12.5
195	2	12-24	-	-	7.8	7.7	55	2		3.64				7.40	75.0	24.0	22	71.0				5.67	43.6	13.0		19.1
196	3	24-48	-	-	8.5	7.8	250	-		1.40				7.40	75.0	20.5	23	95.5				6.44	54.0	11.9		23.0
197	4	48-68	-	-	7.8	7.7	60	1		3.03											6.6		46.0			16.5
198	5	68-120	-	-	9.3	7.9	100	3		.40											5.4		25.0			8.6
199	BW39-1-75	0-12	-	.004	8.0	7.8	40	1		3.64				9.0	90.0	27.9	24	61.0				2.1	37.0	5.8		16.6
200	2	12-36	.06	.08	8.0	7.8	33	2		1.40				7.6	72.0	24.8	20	48.0				1.9	29.0	1.9		9.4
201	3	42-72	-	-	8.5	7.2	53	2		.69											3.2		19.6			6.9
202	4	72-96	-	-	8.4	7.4	70	2		.88											4.2		26.0			9.1
203	5	96-120	-	-	9.5	7.7	245	1		.29											4.4		24.4			11.2
204	BW40-1-75	0-12	.03	.03	8.2	7.6	32	2		2.42				7.2	72.0	22.3	22	48.4				2.1	25.0	8.5		13.4
205	2	36-60	-	-	8.6	7.7	170	-		.99											1.8		56.0			20.6
206	BW41-1-75	0-12	11.2	5.36	9.1	7.6	16	-		.08											.8		12.4			3.5
207	2	12-40	-	-	8.9	7.7	42	3		.69											4.6		19.6			5.9
208	3	48-108	.13	.16	6.2	7.2	55	-		2.75				11.0	112.0	29.9	19	68.5				10.3	58.0	17.8		22.9
209	BW43-1-75	0-12	-	-	7.2	6.9	40	2		.76											1.8		25.0			11.7
210	2	12-22	-	-	8.6	7.2	80	2		.58				4.2	42.0	10.2	19	41.0				4.1	26.0	15.7		9.5
211	3	22-42	-	-	7.7	7.0	80	-		2.21				5.2	45.0	16.2	16	69.7				8.5	44.0	19.2		19.0
212	4	42-78	.22	.12	8.0	7.3	31	1		.95				6.4	60.0	22.4	18	31.4				1.9	19.0	10.1		6.0
213	5	78-120	.19	.06	8.4	7.6	31	-		.61				6.0	58.5	17.6	20	30.6				1.4	11.0	12.8		4.4
214	BW44-1-75	0-12	-	-	8.2	7.8	65	1		1.08				5.6	57.0	15.4	21	61.9				4.9	42.0	11.6		16.8
215	2	12-44	-	-	9.1	7.9	50	1		.55				3.8	40.5	4.6	27	38.9				3.4	21.6	15.8		8.9
216	3	44-72	-	-	9.1	7.7	55	-		.31											2.0		8.2			3.4
217	4	72-94	-	-	9.5	7.8	105	-		.24				1.6	16.5	1.2	21	28.8				1.7	7.6	22.6		3.2
218	5	94-108	.40	.27	8.3	7.7		-		1.24				7.4	73.5	22.9	22	33.0				1.8	15.0	11.8		5.6
219	BW45-1-75	0-12	2.70	1.92	8.6	7.6	16	-		.07											.2		15.2			4.3
220	2	12-42	.08	.01	9.1	7.8	40	-		.24											2.6		14.6			6.9
221	3	42-66	-	-	8.9	7.8	60	1		.74											5.6		23.6			9.0
222	4	66-90	.88	.60	8.0	7.2	27	1		2.14				8.0	81.0	25.8	23	33.1				1.3	16.0	8.3		6.0
223	5	90-120	.13	.18	7.9	7.3	30	2		2.78				8.4	90.0	24.8	26	39.3				3.7	24.0	15.3		8.5
224	BW46-1-75	Surface	.54	1.04	8.7	7.4	25	1		.25											1.8		27.0			8.6
225	2	0-12	.19	.02	8.1	7.6	150	1		2.78				8.4	90.0	22.3	27	101.5				7.9	50.0	15.7		24.5
226	3	12-30	-	-	8.4	7.6	60	1		1.08				6.4	66.0	17.7	22	43.6				2.3	28.0	8.3		16.2
227	4	30-54	.04	.01	8.6	7.8	110	1		.76				5.2	54.0	12.1	22	62.4				3.2	12.8	25.2		8.5
228	5	54-90	-	-	9.2	7.5	65	2		.45											2.4		32.6			15.3
229	6	90-108	-	-	8.6	7.7	200	3		1.20				6.4	67.5	16.2	24	79.3				2.5	24.8	10.0		10.3
230	BW47-1-75	Surface	-	-	9.4	7.8	32	3		.25											2.8		15.0			5.9
231	2	0-12	.30	.24	8.2	7.0	28	1		1.87				10.0	104.0	22.3	31	31.6			-	-	22.0			8.6
232	3	12-30	.33	.37	8.9	7.3	52	1		.84											5.6		22.6			8.2
233	4	36-78	-	-	9.2	7.5	75	-		.55				4.6	45.0	8.2	22	34.0				3.9	16.0	24.2		8.6
234	5	90-120	-	-	9.1	7.6	70	-		.86				7.6	78.0	16.3	27	33.6				3.4	13.0	26.0		6.2
235	BW48-1-75	0-12	-	-	8.9	7.4	17	-		.08											.4		17.0			4.0

Table B-5 (con.)

Results of Laboratory Tests on Auger Hole/Profile Samples (Soil)

LM-813 (Rev. 12/76)
Interior-Reclamation
Lower Missouri Region

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

GPO 838-360/29

Lab Number	Site Number	Depth Inches	Hydraulic Conductivity Ins./hr. 6th Hr.	Hydraulic Conductivity Ins./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Saturation Extract Na Me/L	Saturation Extract Ca+Mg Me/L	Saturation Extract SAR	Saturation Extract Sat %	Saturation Extract Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Na Me/100g Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	% of Moisture 15 Bars
236	BW48-2-75	24-48	2.88	2.26	9.0	7.5	32	-		.23											2.0		16.6			5.7
237	3	48-72	.33	.18	9.2	7.5	36	-		.26											2.2		19.0			5.4
238	4	84-102	.22	.03	9.2	7.7	65	2		.54											4.0		24.0			6.8
239	5	102-120	-	-	8.1	7.8	31	1		3.01											7.4		19.6			7.8
240	BW49-1-75	0-12	.53	.42	8.5	7.8	31	1		1.06				8.4	85.5	24.2	25	35.7				1.2	14.6	8.2		6.2
241	2	12-60	.10	.02	8.2	6.7	26	1		1.29				7.2	72.0	21.2	22	35.7				0.5	15.0	3.3		4.5
242	3	60-78	1.04	.70	8.0	7.3	46	2		2.86				11.0							7.8		23.0			9.9
243	4	78-120	.05	.11	9.1	7.7	150	3		1.21				11.0							6.4		20.8			7.6
244	BW50-1-75	0-12	-	-	9.0	7.8	35	3		.72											1.0		13.0			4.5
245	2	12-36	.01	.01	9.6	7.8	65	2		.39											1.4		7.8			2.9
246	3	36-60	-	-	9.8	7.8	120	1		.40				4.0							3.0		8.0			3.8
247	4	60-84	-	-	8.4	7.7	110	3		2.98				10.8							15.0		44.0			19.1
248	BW51-1-75	0-12	-	-	8.9	7.6	17	2		.07											.1		6.6			2.5
249	2	12-48	5.52	2.28	9.5	7.6	23	3		.16											.6		8.8			3.0
250	3	48-72	2.41	2.48	9.7	7.9	100	3		.47											3.4		15.6			7.5
251	4	72-120	-	-	9.3	7.0	240	3		.65				3.0							9.6		40.0			19.3
252	BW52-1-75	0-12	-	-	8.5	7.4	45	3		2.28				12.0							2.2		15.6			9.1
253	2	12-30	.51	.44	9.5	7.6	90	2		.73				7.4							4.8		12.0			4.4
254	3	30-48	-	-	9.3	7.9	350	2		1.42				5.2							12.0		36.0			17.7
255	4	48-72	-	-	9.4	8.3	260	3		.98				5.6							18.0		40.0			26.4
256	5	72	-	-	9.5	8.3	350	3		.93											19.0		51.0			25.0
257	BW53-1-75	0-12	-	-	8.8	7.5	15	3		.07											.1		12.0			3.4
258	2	12-48	6.06	2.72	9.3	7.6	26	3		.15											1.2		14.4			4.7
259	3	48-96	1.36	2.66	9.2	7.7	20	3		.32				3.0							1.4		9.4			3.4
260	4	96-120	1.24	1.98	9.5	7.9	18	1		.19											.8		3.6			1.7
261	BW54-1-75	0-12	.001	-	8.4	7.0	150	-		3.00				8.8							22.0		52.0			22.1
262	2	12-24	.27	.31	8.4	6.9	225	-		1.78				8.8							22.0		72.0			22.7
263	3	24-36	.09	.13	8.0	6.8	175	-		1.90											16.0		53.0			20.5
264	BW56-1-75	0-10	-	-	8.7	7.4	90	2		.54											5.2		44.0			17.6
265	2	10-24	-	-	8.1	7.5	75	1		1.90				7.6							11.0		40.0			15.9
266	3	24-36	-	.002	8.2	7.6	50	2		1.88											9.6		32.0			10.6
267	4	36-56	-	-	8.9	7.8	325	2		1.13				7.6							12.0		40.0			16.9
268	5	56-72	-	-	9.1	7.9	225	2		1.08											12.0		44.0			16.1
269	6	72-108	-	-	9.1	7.7	125	1		.87											7.0		28.4			10.9
270	7	108-120	-	-	8.0	7.1	125	-		2.82				12.0							22.0		66.0			22.8
271	BW57-1-75	0-12	-	-	9.3	7.1	240	2		.44				2.6							3.0		18.0			6.7
272	2	12-44	.01	.001	9.2	7.3	75	2		.42											2.0		13.0			4.4
273	3	54-90	-	-	9.4	7.5	50	1		.42											3.4		18.0			6.8
274	4	90-120	-	-	9.1	7.7	225	3		.65				4.6							6.0		34.8			11.2
275	BW58-1-75	0-6	6.12	1.20	8.9	7.4	17	-		.08				0.4	1.5	1.8	1.6	28.2			.1		11.8			6.5
276	2	6-28	.04	.05	8.1	7.7	45	1		2.85				8.2	95.0	22.0	29	43.5			5.2		25.4			10.6
277	3	28-38	-	-	8.5	7.6	100	-		1.12				8.0	100.0	24.0	29	41.7			4.0		29.6			11.4
278	4	38-48	-	-	9.3	7.7	80	3		.48				5.3	55.0	6.8	30	31.8			3.4		18.8			12.1
279	5	48-64	-	-	9.0	7.8	90	3		.73				5.6	55.0	9.2	26	46.1			6.0		45.6			6.4
280	6	64-80	-	-	9.0	7.7	70	2		.50				4.5	50.0	7.2	26	37.6			3.0		27.8			8.0
281	7	86-120	.17	.07	8.8	7.0	34	2		.58				6.3	65.0	22.0	19	35.2			2.8					7.5
282	BW59-1-75	0-6	-	.002	9.3	7.6	46	3		.38											3.6		24.0			9.5
283	2	6-36	-	-	8.3	7.5	70	1		2.85				6.8							8.0		48.0			17.5
284	3	36-78	-	-	8.4	7.6	100	-		1.84											8.0		49.0			18.3
285	4	78-88	-	-	9.1	7.7	240	2		.58											1.8		30.0			14.7
286	5	88-114	-	-	8.0	7.6	60	1		2.29											4.8		50.6			17.2
287	6	114-120	-	.004	8.5	7.5	75	1		.88											2.6		27.2			14.3
288	BW60-1-75	0-12	6.56	3.36	8.5	7.5	16	1		1.15											.2					4.4
289	2	12-36	.03	.04	8.0	7.7	47	1		2.87				7.2							5.0		27.0			13.7
290	3	36-58	-	-	8.1	7.8	115	-		2.49				7.2							13.0		57.0			20.2
291	4	58-96	-	-	8.6	7.2	170	1		1.04				5.6							5.8		35.0			15.8
292	5	96-120	-	-	8.1	7.5	85	2		1.90											5.4		50.0			17.7
293	BW61-1-75	0-12	-	.001	9.0	7.8	36			1.04				10.0							3.8		12.0			3.6
294	2	12-48	-	-	9.4	8.0	70			.88											4.2		14.8			5.6
295	3	48-72	-	-	9.7	8.3	175			.70											6.4		17.0			7.7
296	4	72-96	-	-	9.4	8.3	90			.77											3.8		15.0			5.8
297	5	96-108	.26	.24	8.6	8.1	45			.71											5.6		17.6			7.4
298	6	108-120	-	-	9.3	8.2	53			1.65											3.2		8.6			3.8
299	BW62-1-75	0-12	-	-	9.0	7.9	41			.72											4.2		28.0			

Table B-5 (con.)

Results of Laboratory Tests on Auger Hole/Profile Samples (Soil)

LM-813 (Rev. 12/76)
Interior-Reclamation
Lower Missouri Region

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

GPO 838-360/29

Lab Number	Site Number	Depth Inches	Hydraulic Conductivity Inc./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract $ecx10^3$ @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract $ecx10^3$ @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Na Me/100g Total Na	Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	15 Bars
300	BW62-2-75	12-60	.02	.002	9.2	7.8	44			.30											1.2		24.0			6.2
301	3	60-80	.03	.002	9.2	7.0	43			.25											.4		16.0			4.8
302	4	80-120	11.6	4.54	9.2	7.3	28			.17											.6		14.0			-
303	BW63-1-75	0-6	-	-	8.8	7.6	70			.17											7.0		38.0			13.0
304	2	6-36	.04	.002	8.5	7.5	30			.89											5.6		24.0			7.5
305	3	36-60	-	.002	8.5	7.7	60			1.52											3.8		53.0			17.3
306	4	60-84	-	.001	9.2	7.8	47			.41											3.6		20.0			7.0
307	5	84-108	.06	.02	8.3	7.6	42			1.46											5.8		48.0			12.9
308	6	108-132	-	-	8.3	7.6	65			1.42											6.8		54.0			18.0
309	7	132-144	-	-	9.0	7.9	75			.54											6.0		44.0			11.9
310	BW64-1-75	0-6	.03	.02	9.0	7.8	55			.25											3.8		35.0			13.0
311	2	6-14	.12	.11	8.2	7.3	32			1.50											5.4		26.0			9.3
312	3	14-24	.02	.006	8.7	7.5	39	3		.58											2.8		27.0			6.8
313	4	24-48	-	-	9.0	7.7	60	3		.39											3.4		30.0			9.4
314	5	48-84	.46	.53	8.3	7.5	30	3		.60											2.0		19.6			-
315	6	84-120	.02	.001	8.7	7.6	50	-		.34											1.8		16.0			5.3
316	BW65-1-75	0-12	.006	.004	8.5	7.9	40	2		2.71											12.8		33.0			9.5
317	2	12-24	-	-	8.8	7.8	65	2		1.39											8.8		27.0			8.8
318	3	24-60	-	-	9.2	7.8	120	3		.48											3.8		26.0			7.8
319	4	60-90	-	-	9.0	7.9	100	3		.95											6.4		19.6			5.6
320	5	90-120	.04	.01	9.2	8.1	160	1		1.84											6.4		9.2			4.0
321	BW66-1-75	0-12	-	-	9.0	7.4	100	1		.48											5.6		48.0			16.9
322	2	12-24	.03	.02	8.0	7.5	50	1		2.85											7.8		57.0			17.7
323	3	24-48	.04	.02	8.3	7.6	49	1		1.27											7.0		40.0			13.8
324	4	48-66	-	-	8.8	7.9	100	2		.57											5.6		40.0			16.6
325	5	66-96	-	.001	8.3	7.8	75	1		1.42											5.4					-
326	6	96-116	-	.002	9.0	7.9	75	2		.42											4.0		33.0			12.5
327	BW67-1-75	0-12	-	-	8.9	7.8	175	2		.71											5.8		40.0			16.8
328	2	12-42	.001	.08	8.0	7.8	32	2		2.03											5.2		34.0			12.0
329	3	52-60	-	-	8.9	7.8	48	2		.50											2.6		26.0			8.7
330	BW68-1-75	0-20	6.28	6.76	9.1	7.7	24	1		.12											.6		10.0			3.7
331	2	20-34	-	-	9.2	7.9	110	3		.53											3.6		19.6			7.9
332	3	40-60	-	-	9.1	7.7	58	-		.43											2.2		11.6			4.2
333	BW69-1-75	0-6	-	-	8.8	7.7	140	1		.41											5.4		53.0			16.0
334	2	6-12	-	-	8.7	7.8	100	1		.66											4.2		34.0			10.3
335	3	12-48	-	-	8.0	7.6	150	1		1.92											9.6		42.0			12.5

Table B-6

Results of Laboratory Tests on Drill Hole Samples (Bedrock)

LM-813 (Rev. 12/76)
Interior-Reclamation
Lower Missouri Region

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

GPO 838-360/29

Lab Number	Drill Hole (DH) No. — Site Number — Sample No.	Depth Feet	Hydraulic Conductivity Ins./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Saturation Extract Na Me/L	Saturation Extract Ca+Mg Me/L	Saturation Extract SAR	Saturation Extract Ca+Mg Me 100g	Saturation Extract Sat %	Gyp Me 100g	Na Me/100g Total Na	Na Me/100g Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture	% of Moisture 15 Bars
1	BW1-1-75	15-44	-	-	8.4		60	-		.17				1.63	17.7	1.6	20		113			8.2	100	8.2		33.8
2	2	44-63	-	-	9.4		70	-		.23				1.81	15.6	1.2	20		131			.36	74.0	0.5		30.4
3	3	63-77	-	-	10.0		27	1		.46				2.81	25.6	0.6	47		70.4			8.0	68.0	11.8		31.4
4	4	78-128	-	-	9.9		60	2		.52				2.08	19.0	0.8	30		97.8			15.1	55.2	27.5		35.6
5	5	128-160	-	-	10.0		60	3		.40				1.63	13.7	0.2	43		103			16.6	75.2	22.1		38.9
6	6	176-193	-	-	10.0		32	3		.33				1.92	17.0	0.2	54		71.7			11.0	24.0	45.8		38.1
7	7	203-212	-	-	9.8		63	2		.53				2.73	25.5	0.5	51		97.3			17.5	68.0	25.8		29.7
8	8	232-242	-	-	9.6		62	1		.58				6.51	60.0	0.5	120		89.2			12.3	68.0	18.0		28.5
9	9	253-282	-	-	9.7		70	-		.50				2.26	19.0	0.4	42		102			13.1	82.0	15.9		32.7
10	10	287.6-296	-	-	9.8		46	-		.33				1.84	16.0	0.4	36		69.0			9.9	54.0	18.3		28.0
11	11	338-346	-	-	9.6		82	-		.27				1.59	13.6	0.4	30		102			16.8	75.2	22.4		31.1
12	12	357-370	-	-	9.4		26	-		.25				2.56	21.0	0.2	66		42.2			1.1	3.9	27.8		4.3
13	BW2-1-75	17.2-33.7	-	-	9.4		250	2		.47				6.39	56.4	7.4	29		172			14.3	106	13.5		33.6
14	2	33.7-38.4	-	-	8.9		75	3		.78				8.77	82.0	12.4	33		115			16.6	108	15.3		30.2
15	3	39.6-47.7	-	-	9.6		80	1		.52				2.88	25.2	0.6	46		118			19.0	94.0	20.2		31.8
16	4	48.9-58.6	-	-	9.9		105	3		.44				1.65	14.0	0.6	26		155			14.8	74.0	20.1		31.6
17	5	58.6-78.5	-	-	10.0		100	2		.24				1.10	8.8	0.2	28		166			5.9	23.2	25.8		45.2
18	6	82 -96.5	-	-	10.0		220	3		.44				0.94	7.4	0.2	23		213			13.4	70.0	19.2		31.3
19	7	102-132	-	-	9.3		125	-		.78				3.43	32.6	1.0	46		123			15.0	92.0	16.3		35.2
20	8	132-157	-	-	9.7		100	-		.24				1.73	16.7	0.4	37		116			16.1	82.0	19.6		29.9
21	BW3-1-75	12-32	-	-	7.1		37	2		2.20				7.25	56.0	25.2	16		83.8			5.3	74.0	7.2		20.9
22	2	32-52	-	-	9.5		100	2		.72				3.60	32.4	0.6	59		135			22.6	88.0	25.7		30.0
23	3	57-79	-	-	9.9		90	2		.40				2.19	18.0	0.4	40		129			18.7	86.0	21.7		34.4
24	4	79-106	-	-	9.4		75	-		.53				2.15	19.0	0.4	42		109			23.9	80.0	29.9		32.2
25	BW4-1-75	28-69	-	-	8.9		200	-		.70				5.08	45.6	3.4	35		117			19.7	92.0	21.4		30.7
26	2	71-104.8	-	-	9.4		230	-		.14				1.04	7.6	0.2	24		168			8.7	18.0	48.4		26.7
27	BW5-1-75	22-37	-	-	7.9		230	-		1.45				11.1	112	9.2	52		133			23.1	100	23.1		32.9
28	2	37-57	-	-	9.7		205	2		.57				3.64	32.0	0.5	64		134			27.3	102	26.8		36.7
29	3	64-74.8	-	-	9.9		200	1		.38				1.72	15.8	0.4	35		140			24.8	86.0	28.2		42.5
30	4	81-101.5	-	-	9.9		65	3		.53				1.92	16.0	0.4	36		72.6			8.0	15.6	50.2		39.4
31	4	81-101.5	-	-	9.8		110	-		.33				1.29	15.2	0.4	34		117			18.2	72.0	25.3		29.5
32	BW6-1-75	33-50	-	-	9.9		150	-		.41				2.30	22.0	0.6	40		123			15.3	78.0	19.6		29.3
33	2	51-56	-	-	10.0		95	3		.44																
34	3	56-76	-	-	9.7		110	1		.40				1.48	13.8	0.4	31		84			7.6	12.8	59.7		25.3
35	4	76-86	-	-	9.9		150	1		.33				2.82	28.0	0.4	63		129			24.4	90.0	27.1		32.5
36	5	104-133	-	-	9.8		200	1		.22				1.17	11.5	0.4	26		225			22.4	78.0	28.7		37.7
37	BW7-1-75	13-24	-	-	9.8		270	3		.58				0.92	9.5	0.4	21		205			14.1	28.0	50.2		30.5
38	2	24-36	-	-	8.8		100	-		1.03				4.30	43.0	6.0	25		210			6.0	66.0	9.0		27.1
39	BW7-3-75	36-47	-	-	10.1		160	2		.45				6.10	66.0	2.8	56		93			17.9	98.0	18.2		28.3
40	4	47-69	-	-	10.1		57	3		.32				1.65	17.5	0.4	39		132			21.7	92.0	23.6		42.6
41	5	69-78	-	-	9.7		100	1		.45				1.50	16.0	0.4	36		99.4			10.4	24.0	43.4		38.9
42	6	94-104	-	-	10.1		165	1		.31				2.54	27.0	0.6	49		102			19.3	106	18.2		32.4
43	7	104-136	-	-	9.9		105	1		.24				1.52	16.0	0.2	51		160			22.4	76.0	29.5		36.2
44	8	138-174	-	-	9.7		110	-		.49				1.25	12.0	0.3	31		135			8.0	15.6	51.2		33.4
45	9	185-195	-	-	9.7		100	-		.33				1.82	20.0	0.4	45		130			25.4	104	24.4		36.0
														2.15	22.0	0.4	49		944			14.9	72	20.7		28.0

Table B-7
Mechanical Analysis of Soil Samples
Bisti West Study Site, New Mexico

Profile No.	Sample No.	Depth in Inches	Percent Sand	Percent Silt	Percent Clay	Lab. Texture	Field Texture
BW-1	1	0-48	76.0	14.0	10.0	SL	SL
	2	48-72	68.4	16.6	15.0	SL	SCL
	3	72-132	89.4	5.6	5.0	S	S
	4	132-180	86.4	9.6	4.0	LS	S
BW-3	1	0-36	90.6	5.2	4.2	S	LS
	2	36-66	77.6	14.2	8.2	SL	SL
	3	66-84	75.0	14.0	11.0	SL	SL
	4	84-144	94.0	4.0	2.0	S	S
BW-4	1	0-24	7.8	20.0	72.2	C	SiC
	3	84-120	33.0	31.0	36.0	CL	SCL
	4	120-144	61.0	18.0	21.0	SCL	SS
BW-5	1	0-24	45.8	38.2	16.0	L	CL
	2	32-66	78.0	11.0	11.0	SL	LS
	3	66-114	69.0	10.0	21.0	SCL	C
BW-6	1	0-12	24.2	20.8	55.0	C	SiC
	2	12-28	19.6	20.4	60.0	C	SiC
	3	28-36	71.6	11.2	17.2	SL	SL
	4	36-48	25.0	40.6	34.4	CL	CL
	5	48-64	58.2	22.8	19.0	SL	L
	6	64-90	18.4	38.6	43.0	C	SiCL
	7	90-100	53.8	27.0	19.2	SL	SL
	8	100-120	45.0	18.0	37.0	SC	SiC
BW-7	1	0-12	75.4	14.6	10.0	SL	LS
	2	12-34	75.2	14.8	10.0	SL	SL
	3	34-48	72.4	13.4	14.2	SL	SL
	4	48-90	89.2	5.4	5.4	S	LS
	5	90-108	95.0	2.6	2.4	S	S
BW-8	1	0-6	42.2	33.8	24.0	L	CL
	2	6-36	46.0	32.0	22.0	L	SCL
	3	36-76	10.4	35.2	54.4	C	C
	4	76-96	56.0	27.6	16.4	SL	SL
	5	96-120	23.0	36.6	40.4	C	C
BW-9	1	0-12	87.4	6.4	6.2	S	LS
	2	12-48	85.4	4.4	10.2	LS	LS
	3	48-54	52.8	18.8	28.4	SCL	SCL
	4	54-60	45.2	24.4	30.4	SCL	SS
BW-10	1	0-12	63.2	16.4	20.4	SCL	L
	2	12-24	23.6	60.0	16.4	SiL	SS
BW-11	1	0-12	26.0	41.6	32.4	CL	SiCL
	2	12-36	38.4	37.2	24.4	L	SiL
	3	36-52	63.6	24.8	11.6	SL	SL
	4	52-60	41.4	26.4	32.2	CL	SS
BW-12	1	0-12	93.4	3.4	3.2	S	LfS
	2	12-36	90.6	5.2	4.2	S	LfS
	3	36-60	80.4	9.6	10.0	LS	SL
	4	60-82	78.0	10.4	11.6	SL	LS
	5	82-102	27.0	38.6	34.4	CL	SS

Table B-7
Mechanical Analysis of Soil Samples
Bisti West Study Site, New Mexico
(con.)

Profile No.	Sample No.	Depth in Inches	Percent Sand	Percent Silt	Percent Clay	Lab. Texture	Field Texture
BW-14	1	0-12	92.4	4.4	3.2	S	LfS
	2	12-48	90.2	6.2	3.6	S	LfS
	3	48-84	88.4	6.0	5.6	S	LS
	4	84-120	91.8	4.6	3.6	S	LfS
BW-15	1	0-12	87.0	7.4	5.6	LS	LS
	2	12-48	86.0	9.6	4.4	LS	LS
	3	48-64	60.4	27.8	11.8	SL	SL
	4	64-72	87.4	7.2	5.4	LS	L
	5	72-80	74.0	18.4	7.6	SL	LS
	6	80-90	70.0	12.4	17.6	SL	SS
BW-16	1	0-12	35.4	14.6	50.0	C	SiC
	2	12-30	32.8	13.2	54.0	C	SiC
	3	30-46	58.4	22.2	19.4	SL	L
	4	46-58	11.6	48.0	40.4	SiC	SiC
	5	58-84	71.0	18.6	10.4	SL	LfS
	6	84-114	84.8	8.6	6.6	LS	LfS
BW-17	1	0-12	88.0	7.4	4.6	S	LfS
	2	12-36	89.8	5.4	4.8	S	LfS
	3	36-84	91.0	4.4	4.6	S	LfS
	4	84-138	92.4	3.2	4.4	S	LfS
	5	138-162	63.6	18.2	18.2	SL	LS
BW-18	1	0-12	51.6	18.0	30.4	SCL	C
	2	18-42	70.8	13.6	15.6	SL	LfS
	3	42-64	34.2	19.2	46.6	C	C
	4	64-86	83.4	8.2	8.4	LS	fS
	5	86-96	31.2	32.4	36.4	CL	SiC
BW-19	1	0-12	50.2	21.4	28.4	SCL	SC
	2	18-38	17.2	28.2	54.6	C	SiC
	3	38-80	83.6	8.6	7.8	LS	fS
	4	80-102	93.2	2.0	4.8	S	S
	5	102-120	12.0	54.4	33.6	SiCL	C
BW-20	1	0-12	91.6	4.6	3.8	S	fS
	2	12-48	91.0	5.2	3.8	S	fS
	3	48-84	89.8	6.2	4.0	S	fS
	4	84-120	90.2	5.0	4.8	S	fS
BW-21	1	0-12	47.2	25.0	27.8	SCL	CL
	2	14+	9.8	34.2	56.0	C	SS
BW-22	1	0-12	18.6	51.4	30.0	SiCL	C
	2	12-24	49.4	25.0	25.6	SCL	Sh
	3	24-36	7.6	44.2	48.2	SiC	Sh
BW-23	1	0-12	92.6	3.2	4.2	S	fS
	2	12-48	92.8	3.0	4.2	S	fS
	3	48-84	92.0	3.8	4.2	S	fS
	4	84-108	87.6	4.4	8.0	S	LfS
	5	108-120	62.6	12.0	25.4	SCL	SC

Table B-7
Mechanical Analysis of Soil Samples
Bisti West Study Site, New Mexico
(con.)

Profile No.	Sample No.	Depth in Inches	Percent Sand	Percent Silt	Percent Clay	Lab. Texture	Field Texture
BW-24	1	0-12	87.6	8.0	4.4	S	fS
	2	12-48	90.6	5.0	4.4	S	fS
	3	48-96	90.2	5.4	4.2	S	fS
	4	96-120	90.2	5.6	4.2	S	LfS
BW-25	1	0-12	70.8	16.2	13.0	SL	LfS
	2	12-24	83.6	6.2	10.2	LS	LS
	3	24-66	88.8	5.0	6.2	S	fS
	4	66-90	83.6	8.2	8.2	LS	LfS
	5	90-120	51.4	20.4	28.2	SCL	SC
BW-27	1	0-12	53.0	29.6	17.4	SL	SL
	2	12-36	69.0	15.8	15.2	SL	LfS
	3	36-50	90.4	4.2	5.4	S	LS
	4	50-70	85.0	6.8	8.2	LS	SL
	5	70-78	62.0	20.6	17.4	SCL	SCL
BW-29	1	0-12	73.0	12.4	14.6	SL	SL
	2	12-46	78.2	11.6	10.2	SL	SL
	3	46-64	84.2	10.6	5.2	LS	LfS
	4	64-102	88.6	6.2	5.2	S	LfS
BW-30	1	0-12	77.8	12.6	9.6	SL	LS
	2	12-24	35.0	36.6	28.4	CL	C
	3	24-64	30.0	29.8	40.2	C	C
	4	64-84	46.0	21.2	32.8	SCL	CL
	5	84-96	26.8	42.0	31.2	CL	C
BW-31	1	0-12	78.4	14.0	7.6	LS	LfS
	2	12-24	69.0	23.4	7.6	SL	SL
	3	24-44	76.0	7.6	16.4	SL	L
	4	44-120	94.0	16.6	9.4	SL	LfS
BW-32	1	0-12	51.6	28.2	20.2	L	CL
	2	12-24	27.6	34.0	38.4	CL	C
	3	24-60	46.8	30.0	23.2	L	SiCL
	4	60-84	24.0	20.6	55.4	C	C
	5	84-102	78.6	11.4	10.0	SL	L
	6	102-120	22.6	24.6	52.8	C	Sh
BW-33	1	0-12	39.6	34.8	25.6	L	SiCL
	2	12-48	45.2	33.6	21.2	L	SiL
	3	48-66	73.4	11.4	15.2	SL	LfS
	4	66-84	28.0	23.8	48.2	C	C
	Surface		45.6	35.6	18.8	L	
BW-34	1	0-12	56.6	28.6	14.8	SL	SL
	2	12-36	64.8	20.0	15.2	SL	SL
	3	36-72	51.0	27.0	22.0	SCL	SCL
	4	72-84	83.2	8.0	8.8	LS	S
BW-35	1	0-12	51.0	24.2	24.8	SCL	C
	2	12-24	35.6	35.6	28.8	CL	CL
	3	24-48	32.2	44.0	23.8	L	SiL
	4	48-84	76.8	11.0	12.2	SL	LS
	5	84-120	73.6	13.4	13.0	SL	LfS

Table B-7
Mechanical Analysis of Soil Samples
Bisti West Study Site, New Mexico
(con.)

Profile No.	Sample No.	Depth in Inches	Percent Sand	Percent Silt	Percent Clay	Lab. Texture	Field Texture
BW-36	1	0-12	31.6	42.0	26.4	L	SiCL
	2	12-30	47.2	31.8	21.0	L	CL
	3	30-60	60.4	21.6	18.0	SL	SL
	4	60-84	42.8	28.8	28.4	CL	SCL
	5	84-120	66.0	19.6	14.4	SL	LfS
BW-37	1	0-12	46.6	21.4	32.0	SCL	CL
	2	12-30	37.2	23.0	39.8	CL	C
	3	30-72	57.0	25.4	17.6	SL	LfS
	4	72-96	55.6	19.2	25.2	SCL	LfS
BW-38	1	0-12	47.2	25.6	27.2	SCL	CL
	2	12-24	21.6	26.4	52.0	C	C
	3	24-48	13.6	27.2	59.2	C	C
	4	48-68	37.6	26.8	35.6	CL	C
	5	68-120	46.6	34.6	18.8	L	L
BW-39	1	0-12	28.2	33.4	38.4	CL	CL
	2	12-36	53.6	20.8	25.6	SCL	SCL
	3	42-72	74.0	12.8	13.2	SL	LfS
	4	72-96	60.0	17.6	22.4	SCL	SCL
	5	96-120	56.4	17.0	26.6	SCL	SCL
BW-40	1	0-12	31.8	34.6	33.6	CL	CL
	2	36-60	16.4	30.4	53.2	C	SiC
BW-41	1	0-12	87.6	6.2	6.2	LS	LS
	2	12-40	78.0	8.8	13.2	SL	SL
	4	48-108	32.0	20.4	47.6	C	Sh
BW-43	1	0-12	42.0	32.8	25.2	CL	SiCL
	2	12-22	55.6	23.0	21.4	SCL	SiCL
	3	22-42	25.2	35.4	39.4	CL	SiC
	4	42-78	72.8	14.0	13.2	SL	SiL
	5	78-120	81.4	9.4	9.2	LS	LfS
BW-44	1	0-12	33.6	30.2	36.2	CL	SiC
	2	12-44	49.8	27.0	23.2	SCL	CL
	3	44-72	89.4	8.4	2.2	S	LfS
	4	72-94	93.4	3.4	3.2	S	S
	5	94-108	71.2	19.0	9.8	SL	LS
BW-45	1	0-12	81.2	9.6	9.2	LS	LfS
	2	12-42	68.6	17.8	13.6	SL	SL
	3	42-66	61.8	19.4	18.8	SL	SL
	4	66-90	74.2	14.8	11.0	SL	SL
	5	90-120	46.8	35.4	17.8	L	L
BW-46	1	Surface	53.2	24.4	22.4	SCL	SiCL
	2	0-12	21.8	29.0	49.2	C	C
	3	12-30	70.4	9.8	19.8	SL	SL
	4	30-54	50.4	17.2	32.4	SCL	C
	5	54-90	78.7	10.7	10.6	SL	SL
	6	90-108	29.8	35.8	34.4	CL	C

Table B-7
Mechanical Analysis of Soil Samples
Bisti West Study Site, New Mexico
(con.)

Profile No.	Sample No.	Depth in Inches	Percent Sand	Percent Silt	Percent Clay	Lab. Texture	Field Texture
BW-47	1	Surface	60.6	17.4	22.0	SCL	SiCL
	2	0-12	68.6	19.6	11.8	SL	LfS
	3	12-30	61.2	23.0	15.8	SL	SiL
	4	36-78	66.8	15.6	17.6	SL	SL
	5	90-120	76.8	10.8	12.4	SL	LS
BW-48	1	0-12	81.0	9.4	9.6	LS	LfS
	2	24-48	73.6	13.2	13.2	SL	L
	3	48-72	74.6	13.6	11.8	SL	LfS
	4	84-102	57.6	26.6	15.8	SL	L
	5	102-120	60.8	20.2	19.0	SL	L
BW-49	1	0-12	69.2	15.2	15.6	SL	SL
	2	12-60	77.0	13.2	9.8	SL	fSL
	3	60-78	54.4	21.6	24.0	SCL	SCL
	4	78-120	60.2	22.0	17.8	SL	L
BW-50	1	0-12	86.1	7.5	6.4	LS	LS
	2	12-36	92.6	3.6	3.8	S	LfS
	3	36-60	88.4	7.0	4.6	S	S
	4	60-84	18.8	27.0	54.2	C	Sh
BW-51	1	0-12	86.8	7.6	5.6	LS	LS
	2	12-48	85.2	7.2	7.6	LS	LS
	3	48-72	72.2	10.8	17.0	SL	SL
	4	72-120	24.2	28.2	47.6	C	Sh
BW-52	1	0-12	75.8	9.8	14.4	SL	SL
	2	12-30	79.4	9.8	10.8	SL	SL
	3	30-48	33.2	19.2	47.6	C	C
	4	48-72	28.0	30.4	41.6	C	Sh
	5	72+	81.6	6.8	11.6	SL	Sh
BW-53	1	0-12	87.0	6.0	7.0	LS	LfS
	2	12-48	82.0	8.4	9.6	LS	LfS
	3	48-96	86.4	6.0	7.6	LS	LfS
	4	96-120	90.6	0.8	8.6	S	fS
BW-54	1	0-12	19.4	17.6	63.0	C	C
	2	12-24	14.2	22.0	63.8	C	Sh
	3	24-36	11.6	29.6	58.8	C	SS
BW-56	1	0-10	12.0	44.4	43.6	SiC	SiCL
	2	10-24	34.2	22.2	43.6	C	C
	3	24-36	58.0	13.6	28.4	SCL	SCL
	4	36-56	30.0	30.6	39.4	CL	SiC
	5	56-72	25.0	45.6	29.4	CL	SiCL
	6	72-108	59.8	17.8	22.4	SCL	C
	7	108-120	18.4	28.0	53.6	C	C
BW-57	1	0-12	74.2	7.2	18.6	SL	SL
	2	12-44	84.8	7.2	8.0	LS	LfS
	3	54-90	76.6	6.4	17.0	SL	LS
	4	90-120	46.4	31.6	22.0	L	CL

Table B-7
Mechanical Analysis of Soil Samples
Bisti West Study Site, New Mexico
(con.)

Profile No.	Sample No.	Depth in Inches	Percent Sand	Percent Silt	Percent Clay	Lab. Texture	Field Texture
BW-58	1	0-6	85.0	5.8	9.2	LS	LfS
	2	6-28	57.8	13.6	28.6	SCL	CL
	3	28-38	56.2	15.4	28.4	SCL	CL
	4	38-48	78.6	9.0	12.4	SL	SL
	5	48-64	52.4	24.4	23.2	SCL	CL
	6	64-80	73.0	8.6	18.4	SL	LS
	7	86-120	70.2	14.4	15.4	SL	L
BW-59	1	0-6	58.0	11.6	30.4	SCL	CL
	2	6-36	26.4	27.2	46.4	C	C
	3	36-78	30.6	15.2	54.2	C	C
	4	78-88	52.4	13.6	34.0	SCL	SCL
	5	88-114	25.0	26.2	48.8	C	C
	6	114-120	53.2	21.2	25.6	SCL	SCL
BW-60	1	0-12	85.8	8.6	5.6	LS	LfS
	2	12-36	47.0	11.4	41.6	SC	C
	3	36-58	15.8	18.4	65.8	C	C
	4	58-96	40.6	14.6	44.8	C	C
	5	96-120	25.0	21.2	53.8	C	C
BW-61	1	0-12	87.4	5.0	7.6	LS	LfS
	2	12-48	73.2	13.0	13.8	SL	SL
	3	48-72	65.8	16.4	17.8	SL	L
	4	72-96	73.2	24.8	12.0	SL	SL
	5	96-108	67.2	13.8	19.0	SL	L
	6	108-120	56.6	23.4	20.0	SL	SL
BW-62	1	0-12	49.2	31.2	19.6	L	L
	2	12-60	65.2	17.8	17.0	SL	LS
	3	60-80	78.0	12.0	10.0	SL	SL
	4	80-120	95.6	0.4	4.0	S	S
BW-63	1	0-6	32.0	45.0	33.0	CL	CL
	2	6-36	60.0	20.2	19.8	SL	SL
	3	36-60	8.0	56.0	36.0	SiCl	SiCL
	4	60-84	60.4	25.6	14.0	SL	SL
	5	84-108	35.6	31.6	32.8	CL	SiCL
	6	108-132	20.2	31.0	48.8	C	SiCL
	7	132-144	35.0	43.2	21.8	L	SiCL
BW-64	1	0-6	41.4	24.6	34.0	CL	CL
	2	6-14	50.2	25.6	24.2	SCL	CL
	3	14-24	65.8	18.2	16.0	SCL	SL
	4	24-48	55.4	26.0	18.6	SL	SiL
	5	48-84	68.0	20.0	12.0	SL	SL
	6	84-120	84.4	2.2	13.4	LS	LS
BW-65	1	0-12	47.6	28.0	24.4	L	CL
	2	12-24	49.4	24.4	26.2	SCL	CL
	3	24-60	64.2	19.2	16.6	SL	SL
	4	60-90	71.6	13.0	15.4	SL	SL
	5	90-120	84.0	3.6	12.4	LS	S
BW-66	1	0-12	28.0	28.6	43.4	C	C
	2	12-24	32.0	25.6	42.4	C	C
	3	24-48	15.6	56.0	28.4	SiCL	CL
	4	48-66	30.0	31.6	38.4	CL	C
	5	66-96	13.4	44.4	42.4	SiC	C
	6	96-116	24.2	51.8	24.0	C	CL

Table B-7
Mechanical Analysis of Soil Samples
Bisti West Study Site, New Mexico
(con.)

Profile No.	Sample No.	Depth in Inches	Percent Sand	Percent Silt	Percent Clay	Lab. Texture	Field Texture
BW-67	1	0-12	33.6	28.6	37.8	CL	C
	2	12-42	25.2	49.6	25.2	L	CL
	3	52-60	65.2	16.2	18.6	SL	L
BW-68	1	0-20	88.6	3.4	8.0	LS	LS
	2	20-34	75.2	6.6	18.2	SL	SL
	3	40-60	90.2	1.6	8.2	S	LfS
BW-69	1	0-6	40.0	25.8	34.2	CL	CL
	2	6-12	66.2	11.4	22.4	SCL	SCL
	3	12-18	54.8	14.8	30.4	SCL	SCL

Table B-8 Note

The following table is useful to those who need information about soils used as structural material or as foundation on which structures are built. Further information can be found in any recently published soil survey by USDA-SCS.

Information under "potential native plant community" is useful to range conservationists and others in range management.

Table B-8

NM0191

SOIL SURVEY INTERPRETATIONS

MLRA(S): 37
TLP.CWK, 1-74
TYPIC TORRIORTHENTS, FINE-LOAMY, MIXED (CALCAREOUS), MESIC

TURLEY SERIES

THE TURLEY SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS. THEY FORMED ON ALLUVIAL FANS IN VALLEY-FILLING SIDE SLOPES FROM MIXED ALLUVIUM. SLOPES ARE FROM 0 TO 5 PERCENT. ELEVATIONS RANGE FROM 4800 TO 6000 FEET. MEAN ANNUAL PRECIPITATION RANGES FROM 6 TO 10 INCHES. MEAN ANNUAL AIR TEMPERATURES RANGE FROM 50 TO 54 DEGREES F. AND THE FROST-FREE SEASON IS ABOUT 155 DAYS. TYPICALLY, THE SURFACE LAYER IS A GRAYISH-BROWN CLAY LOAM, ABOUT 3 INCHES THICK. THE UNDERLYING MATERIAL IS A LIGHT YELLOWISH-BROWN CLAY LOAM AND PALE YELLOW SANDY CLAY LOAM: TO 80 INCHES

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-3	L	ML, CL-ML	A-4	0	100	100	85-100	60-75	25-35	5-10
0-3	CL	CL	A-6	0	100	100	85-100	65-80	30-40	10-20
3-57	CL, SICL	CL	A-6	0	100	100	85-100	65-80	30-40	10-20
57-80	SCL	SC, CL, SM-SC, CL-ML	A-4, A-6	0	100	100	80-90	35-55	25-35	5-15

DEPTH (IN.)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	CORROSIVITY STEEL	CORROSIVITY CONCRETE	EROSION FACTORS K	T	WIND EROD. GROUP
0-3	0.6-2.0	0.14-0.17	7.4-8.4	2-4	LOW	HIGH	LOW	.28	5	4L
0-3	0.2-0.6	0.15-0.19	7.4-8.4	2-4	MODERATE	HIGH	LOW	.28	5	4L
3-57	0.2-0.6	0.15-0.19	7.4-8.4	2-4	MODERATE	HIGH	LOW	.28		
57-80	0.6-2.0	0.14-0.16	7.4-8.4	2-4	MODERATE	HIGH	LOW	.28		

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		B	LOW

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	MODERATE-PERCS SLOWLY
SEWAGE LAGOON AREAS	0-2%: SLIGHT 2+%: MODERATE-SLOPE
SANITARY LANDFILL (TRENCH)	SLIGHT
SANITARY LANDFILL (AREA)	SLIGHT
DAILY COVER FOR LANDFILL	FAIR-TOO CLAYEY

COMMUNITY DEVELOPMENT

SHALLOW EXCAVATIONS	MODERATE-TOO CLAYEY
DWELLINGS WITHOUT BASEMENTS	MODERATE-SHRINK-SWELL
DWELLINGS WITH BASEMENTS	MODERATE-SHRINK-SWELL
SMALL COMMERCIAL BUILDINGS	0-4%: MODERATE-SHRINK-SWELL 4+%: MODERATE-SHRINK-SWELL,SLOPE
LOCAL ROADS AND STREETS	MODERATE-LOW STRENGTH,SHRINK-SWELL
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	

SOURCE MATERIAL

ROADFILL	FAIR-LOW STRENGTH,SHRINK-SWELL
SAND	UNSUITED
GRAVEL	UNSUITED
TOPSOIL	FAIR-TOO CLAYEY

WATER MANAGEMENT

POND RESERVOIR AREA	0-2%: FAVORABLE 2+%: SLOPE
EMBANKMENTS DIKES AND LEVEES	LOW STRENGTH,SHRINK-SWELL,PIPING
EXCAVATED PONDS AQUIFER FED	NO WATER
DRAINAGE	0-1%: PERCS SLOWLY 1+%: SLOPE,PERCS SLOWLY
IRRIGATION	0-1%: PERCS SLOWLY 1-5%: ERODES EASILY,SLOPE,PERCS SLOWLY
TERRACES AND DIVERSIONS	PERCS SLOWLY,PIPING
GRASSED WATERWAYS	

REGIONAL INTERPRETATIONS

RECREATION

CAMP AREAS	CL: MODERATE-PERCS SLOWLY, TOO CLAYEY L: MODERATE-PERCS SLOWLY	PLAYGROUNDS	0-2% CL: MODERATE-PERCS SLOWLY, TOO CLAYEY 0-2% L: MODERATE-PERCS SLOWLY 2+% CL: MODERATE-PERCS SLOWLY, SLOPE, TOO CLAYEY 2+% L: MODERATE-SLOPE, TOO CLAYEY
PICNIC AREAS	CL: MODERATE-TOO CLAYEY L: SLIGHT	PATHS AND TRAILS	CL: MODERATE-TOO CLAYEY L: SLIGHT

CAPABILITY AND PREDICTED YIELDS -- CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY		ALFALFA HAY (TONS)		CORN (BU)		CORN SILAGE (TONS)		GRASS HAY (TONS)		GRAIN SORGHUM (BU)		PASTURE (AUM)		APPLES (BU)	
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-1%	7C	2C	-	6.8	-	115	-	19.6	-	5	-	105	-	14	-	730
1-3%	7E	2E	-	6.8	-	108	-	18.6	-	5	-	93	-	13	-	730
3+%	7E	3E	-	6.0	-	95	-	16.3	-	4	-	75	-	12	-	695

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	IMPORTANT TREES	SITE INDX	TREES TO PLANT
							NONE		

(MANAGEMENT PROBLEMS: EROSION HAZARD through PLANT COMPET.; POTENTIAL PRODUCTIVITY: IMPORTANT TREES, SITE INDX)

WINDBREAKS

CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
IRR	ORIENTAL ARBORVITAE	10	SIBERIAN ELM	45	RUSSIAN-OLIVE	20	HACKBERRY	45
	MULTIFLORA ROSE	4	HONEYLOCUST	45	ROCKY MT. JUNIPER	23	EASTERN REDCEDAR	20

WILDLIFE HABITAT SUITABILITY

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
1-3% IRR	GOOD	GOOD	POOR	-	-	POOR	GOOD	POOR	FAIR	-	FAIR	POOR
3+% IRR	FAIR	GOOD	POOR	-	-	POOR	POOR	V. POOR	FAIR	-	V. POOR	POOR
NIRR	V. POOR	V. POOR	POOR	-	-	POOR	POOR	V. POOR	V. POOR	-	V. POOR	POOR
0-1% IRR	GOOD	GOOD	POOR	-	-	POOR	GOOD	FAIR	FAIR	-	FAIR	POOR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: ALL				
BIG SAGEBRUSH	ARTR2	5				
BLUE GRAMA	BOGR2	20				
FOURWING SALTBUSH	ATCA2	5				
OTHER PERENNIAL FORBS	PPFF	5				
GALLETA	HIJA	15				
INDIAN RICEGRASS	ORHY	5				
NEEDLEANDTHREAD	STCO4	5				
WESTERN WHEATGRASS	AGSM	20				
ALKALI SACATON	SPAI	20				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS		750				
NORMAL YEARS		500				
UNFAVORABLE YEARS		300				

FOOTNOTES

A ENGINEERING PROPERTIES ESTIMATES BASED ON DATA FROM 10 INDIVIDUAL HORIZON SAMPLES FROM SAN JUAN COUNTY, NEW MEXICO.
I RATE MODERATE DUE TO SEMI ARID CLIMATE.

NM0185 SOIL SURVEY INTERPRETATIONS

MLRA(S): 37
TLP,CWK, 1-74
TYPIC HAPLARGIDS, COARSE-LOAMY, MIXED, MESIC

SHIPROCK SERIES

THE SHIPROCK SERIES CONSISTS OF DEEP, WELL-DRAINED SOILS. THEY FORMED IN ALLUVIAL DEPOSITS ON MESA TOPS AND UPLANDS. SLOPES ARE 0 TO 15 PERCENT. ELEVATIONS RANGE FROM 5300 TO 6600 FEET. MEAN ANNUAL PRECIPITATION RANGES FROM 6 TO 10 INCHES. MEAN ANNUAL AIR TEMPERATURES RANGE FROM 50 TO 54 DEGREES F, AND THE FROST-FREE SEASON IS 140 TO 160 DAYS. TYPICALLY, THE SURFACE LAYER IS A BROWN FINE SANDY LOAM, ABOUT 3 INCHES THICK. THE SUBSOIL IS A BROWN FINE SANDY LOAM, ABOUT 9 INCHES THICK. THE SUBSTRATUM IS A BROWN AND VERY PALE BROWN FINE SANDY LOAM AND SANDY LOAM TO 60 INCHES

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-3	SL, FSL	SM, SM-SC	A-2, A-4	0	100	100	75-90	30-50	<30	NP-10
0-3	LS	SM, SP-SM	A-2, A-3	0	100	100	65-85	5-30	<30	NP-5
3-60	SL, FSL	SM, SM-SC	A-2, A-4	0	100	100	75-90	30-50	<30	NP-10

DEPTH (IN.)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	CORROSIVITY STEEL	CORROSIVITY CONCRETE	EROSION FACTORS K	T	WIND EROD. GROUP
0-3	0.6-2.0	0.09-0.12	7.4-8.4	<2	LOW	HIGH	LOW	.24	5	3
0-3	2.0-6.0	0.06-0.09	7.4-8.4	<2	LOW	HIGH	LOW	.15	5	2
3-60	2.0-6.0	0.09-0.12	7.4-8.4	<4	LOW	HIGH	LOW	.24		

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		B	LOW

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	0-8%: SLIGHT 8+%: MODERATE-SLOPE
SEWAGE LAGOON AREAS	0-7%: SEVERE-SEEPAGE 7+%: SEVERE-SLOPE,SEEPAGE
SANITARY LANDFILL (TRENCH)	SLIGHT
SANITARY LANDFILL (AREA)	0-8%: SLIGHT 8+%: MODERATE-SLOPE
DAILY COVER FOR LANDFILL	0-8%: GOOD 8+%: FAIR-SLOPE

COMMUNITY DEVELOPMENT

SHALLOW EXCAVATIONS	0-8%: SLIGHT 8+%: MODERATE-SLOPE
DWELLINGS WITHOUT BASEMENTS	0-8%: SLIGHT 8+%: MODERATE-SLOPE
DWELLINGS WITH BASEMENTS	0-8%: SLIGHT 8+%: MODERATE-SLOPE
SMALL COMMERCIAL BUILDINGS	0-4%: SLIGHT 4-8%: MODERATE-SLOPE 8+%: SEVERE-SLOPE
LOCAL ROADS AND STREETS	0-8%: MODERATE-LOW STRENGTH 8+%: MODERATE-SLOPE,LOW STRENGTH
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	

SOURCE MATERIAL

ROADFILL	FAIR-LOW STRENGTH
SAND	POOR-EXCESS FINES
GRAVEL	UNSUITED
TOPSOIL	0-8% SL,FSL: GOOD LS: POOR-TOO SANDY 8+% SL,FSL: FAIR-SLOPE

WATER MANAGEMENT

POND RESERVOIR AREA	0-2%: SEEPAGE 2+%: SLOPE,SEEPAGE
EMBANKMENTS DIKES AND LEVEES	SEEPAGE,PIPING
EXCAVATED PONDS AQUIFER FED	NO WATER
DRAINAGE	0-1%: FAVORABLE 1+%: SLOPE
IRRIGATION	0-1%: DROUGHTY,FAST INTAKE,SOIL BLOWING 1+%: SLOPE,DROUGHTY,FAST INTAKE
TERRACES AND DIVERSIONS	0-4%: SOIL BLOWING 4+%: SLOPE,SOIL BLOWING
GRASSED WATERWAYS	

REGIONAL INTERPRETATIONS

RECREATION

CAMP AREAS	C-8%: MOOERATE-OUSTY 8+%: MOOERATE-OUSTY.SLOPE	PLAYGROUNDS	0-2%: MOOERATE-OUSTY 2-6%: MOOERATE-SLOPE.OUSTY 6+%: SEVERE-SLOPE
PICNIC AREAS	0-8%: MOOERATE-OUSTY 8+%: MODERATE-OUSTY.SLCPE	PATHS AND TRAILS	MODERATE-OUSTY

CAPABILITY AND PREDICTED YIELDS -- CROPS AND PASTURE (HIGH LEVEL MANAGEMENT) (B)

CLASS-DETERMINING FHASE	CAPA-BILITY		ALFALFA HAY (TONS)		CORN SILAGE (TONS)		GRAIN SORGHUM (BU)		PASTURE (AUM)		CORN (BU)		APPLES (BU)			
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-2% SL.FSL	7E	2E	-	7.0	-	21	-	107	-	14	-	119	-	700		
2-5% SL.FSL	7E	3E	-	7.0	-	21	-	107	-	14	-	119	-	700		
5-8% SL.FSL	7E	4E	-	6.4	-	19	-	102	-	12	-	111	-	700		
8+%	7E	-	-	-	-	-	-	-	-		-	-	-	-		
0-2% LS	7E	3E	-	6.6	-	18	-	94	-	13	-	105	-	630		
2-5% LS	7E	4E	-	6.6	-	18	-	94	-	13	-	105	-	630		

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS: EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	POTENTIAL PRODUCTIVITY: IMPORTANT TREES	SITE INDX	TREES TO PLANT
							NONE		

WINDBREAKS

CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
IRR	ORIENTAL ARBORVITAE	10	SIBERIAN ELM	45	RUSSIAN-OLIVE	20	HACKBERRY	45
	MULTIFLCRA RCSE	4	HONEYLOCUST	45	ROCKY.MT. JUNIPER	23	EASTERN REDCEOAR	20

WILDLIFE HABITAT SUITABILITY

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS: GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	POTENTIAL AS HABITAT FOR: OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
ALL.NIRR	V. POOR	V. POOR	POOR	-	-	POOR	POOR	V. POOR	V. POOR	-	V. POOR	POOR
0-2% LS.IRR	FAIR	GOOD	POOR	-	-	POOR	FAIR	POOR	FAIR	-	POOR	POOR
2-5% LS.IRR	FAIR	GOOD	POOR	-	-	POOR	POOR	V. POOR	FAIR	-	V. POOR	POOR
0-2% SL.FSL.IRR	GOOD	GOOD	POOR	-	-	POOR	GOOD	POOR	FAIR	-	FAIR	POOR
2-5% SL.FSL.IRR	FAIR	GOOD	POOR	-	-	POOR	FAIR	V. POOR	FAIR	-	V. POOR	POOR
5-8% SL.FSL.IRR	FAIR	GOOD	POOR	-	-	POOR	POOR	V. POOR	FAIR	-	V. POOR	POOR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: SL.FSL	LS			
WINTERFAT	EULA5	5	-			
GIANT DROPSEED	SPGI	10	10			
SAND DROPSEED	SPCR	5	5			
INDIAN RICEGRASS	ORHY	25	15			
OTHER PERENNIAL FORBS	PPFF	5	5			
BLUE GRAMA	BOGR2	20	5			
NEWMEXICO FEATHERGRASS	STNE2	5	5			
BIG SAGEBRUSH	ARTR2	5	-			
GALLETA	HIJA	5	-			
LONGLEAF EPHEDRA	EPTR	5	5			
FOURWING SALTBUSH	ATCA2	10	5			
SAND BLUESTEM	ANHA	-	15			
LITTLE BLUESTEM	ANSC2	-	15			
SAND SAGEBRUSH	ARFI2	-	5			
SIDEOATS GRAMA	BOCU	-	10			
POTENTIAL PRODUCTION (LBS./AC. DRY WT): FAVORABLE YEARS		900	1200			
NORMAL YEARS		600	800			
UNFAVORABLE YEARS		300	400			

FOOTNOTES

A ESTIMATES OF ENGINEERING PROPERTIES BASED ON ANALYTICAL DATA OF 8 PEDONS FROM SAN JUAN COUNTY, NEW MEXICO.
B PREDICTED YIELDS BASED ON SPRINKLE METHOD OF IRRIGATION ONLY.

NM0076 SOIL SURVEY INTERPRETATIONS

MLRA(S): 37
HEB, 11-73
TYPIC HAPLARGIDS, FINE-LOAMY, MIXED, MESIC

DOAK SERIES

THE OOAK SERIES CONSISTS OF DEEP, WELL DRAINED SOILS. FORMED IN MIXEO ALLUVIUM OR EOLIAN MATERIAL ON MESAS TOP. SLOPES 0 TO 5 PERCENT. ELEVATION RANGE 54D0 TO 62D0 FEET. MEAN ANNUAL PRECIPITATION IS 6 TO 10 INCHES. MEAN ANNUAL AIR TEMPERATURE IS 50 TO 54 F AND THE FROST FREE PERIOD IS 146 TO 16D DAYS. TYPICALLY THE SURFACE LAYER IS A 8ROWN CLAY LOAM A8OUT 5 INCHES THICK, THE SU8SOIL IS A CLAY LOAM A8OUT 38 INCHES THICK AND THE SU8STRATUM IS A CALCAREOUS CLAY LOAM.

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-5	L	ML	A-4	0	100	10D	80-95	6D-75	<30	NP-5
0-5	FSL	SM, ML	A-4	0	100	10D	80-95	40-6D	<3D	NP-5
0-5	CL	CL, CL-ML	A-6, A-4	0	100	100	90-100	65-80	25-40	5-20
5-60	CL, SICL, L	CL, CL-ML	A-6, A-4	0	1D0	100	8D-100	60-8D	25-40	5-20

DEPTH (IN.)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	CORROSIVITY STEEL	CORROSIVITY CONCRETE	EROSION FACTORS K	EROSION FACTORS T	WIND EROD. GROUP
0-5	0.6-2.0	0.13-D.17	7.4-8.4	<2	LOW	MODERATE	LOW	.37	5	5
0-5	2.0-6.0	0.08-0.13	7.4-8.4	<2	LOW	MOOERATE	LOW	.28	5	3
0-5	0.2-0.6	0.15-D.19	7.4-B.4	<2	MODERATE	MOOERATE	LOW	.32	5	6
5-60	0.2-0.6	0.15-D.19	7.4-9.0	2-4	MODERATE	HIGH	LOW	.37		

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		B	LOW

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	SEVERE-PERCS SLOWLY
SEWAGE LAGOON AREAS	0-2%: SLIGHT 2+%: MODERATE-SLOPE
SANITARY LANDFILL (TRENCH)	SLIGHT
SANITARY LANDFILL (AREA)	SLIGHT
DAILY COVER FOR LANDFILL	FAIR-TOO CLAYEY

COMMUNITY DEVELOPMENT

SHALLOW EXCAVATIONS	SLIGHT
DWELLINGS WITHOUT BASEMENTS	MODERATE-SHRINK-SWELL,LOW STRENGTH
DWELLINGS WITH BASEMENTS	MODERATE-SHRINK-SWELL,LOW STRENGTH
SMALL COMMERCIAL BUILDINGS	0-4%: MODERATE-SHRINK-SWELL,LOW STRENGTH 4+%: MODERATE-SHRINK-SWELL,LOW STRENGTH, SLOPE
LOCAL ROADS AND STREETS	SEVERE-LOW STRENGTH

REGIONAL INTERPRETATIONS

SOURCE MATERIAL

ROADFILL	POOR-LOW STRENGTH
SAND	UNSUITED
GRAVEL	UNSUITED
TOPSOIL	FAIR-TOO CLAYEY

WATER MANAGEMENT

POND RESERVOIR AREA	0-2%: FAVORABLE 2+%: SLOPE
EMBANKMENTS DIKES AND LEVEES	SHRINK-SWELL,LOW STRENGTH,COMPRESSIBLE
EXCAVATED PONDS AQUIFIER FED	NO WATER
DRAINAGE	PERCS SLOWLY
IRRIGATION	0-1%: FAVORABLE 1+%: ERODES EASILY,SLOPE
TERRACES AND DIVERSIONS	ERODES EASILY
GRASSED WATERWAYS	ERODES EASILY

RECREATION

CAMP AREAS	MODERATE-DUSTY	PLAYGROUNDS	0-2%: MODERATE-DUSTY 2-5%: MODERATE-SLOPE,DUSTY
PICNIC AREAS	MODERATE-DUSTY	PATHS AND TRAILS	MODERATE-DUSTY

CAPABILITY AND PREDICTED YIELDS -- CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-1%	7C	1														
1-3%	7E	2E														
3+%	7E	3E														

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS: EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	POTENTIAL PRODUCTIVITY: IMPORTANT TREES	SITE INDX	TREES TO PLANT
							NONE		

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
ALL,IRR	EASTERN REDCEDAR SIBERIAN ELM		ROCKY MT. JUNIPER WHITE MULBERRY		RUSSIAN-OLIVE SKUNKBUSH SUMAC		HONEYLOCUST	

WILDLIFE HABITAT SUITABILITY

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS: GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	POTENTIAL AS HABITAT FOR: OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
ALL,NIRR	V. POOR	V. POOR	POOR	-	-	POOR	POOR	V. POOR	V. POOR	-	V. POOR	POOR
0-3% IRR	GOOD	GOOD	GOOD	-	-	POOR	FAIR	FAIR	GOOD	-	FAIR	-
3+% IRR	FAIR	GOOD	GOOD	-	-	POOR	POOR	V. POOR	FAIR	-	V. POOR	-

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: CL	L			
BIG SAGEBRUSH 1/	ARTR2	5	5			
BLUE GRAMA	BOGR2	20	25			
FOURWING SALTBUSH	ATCA2	5	5			
SIDEOATS GRAMA	BOCU	-	5			
GALLETA	HIJA	15	10			
INDIAN RICEGRASS	ORHY	5	10			
NEEDLE-AND-THREAD	STCO4	5	10			
WESTERN WHEATGRASS	AGSM	20	15			
BOTTLEBRUSH SQUIRRELTAIL	SIHY	-	5			
ALKALI SACATON	SPAI	20	-			
SAND DROPSEED	SPCR	-	5			
OTHER ANNUAL FORBS	AAFF	5	5			
POTENTIAL PRODUCTION (LBS./AC. DRY WT): FAVORABLE YEARS		750	800			
NORMAL YEARS		500	600			
UNFAVORABLE YEARS		300	400			

FOOTNOTES

A ESTIMATES BASED ON HIGHWAY TEST DATA OF 2 PEDON, AND CHARACTERIZATION DATA OF 2 PEDON FROM SAN JUAN COUNTY, N.M.

1 NOT USUALLY UTILIZED BY CATTLE. UTILIZED BY SHEEP IN THE SPRING AND FALL.

SOIL SURVEY INTERPRETATIONS

MLRA(S) 26 — KIND OF UNIT SERIES — UNIT NAME MAYQUEEN
STATE NEVADA — RECORD NO. 138 — AUTHOR(S) WH — DATE 3-75 — REVISED — UNIT MODIFIER

CLASSIFICATION AND BRIEF SOIL DESCRIPTION

MAYQUEEN SERIES CONSISTS OF DEEP SOMEWHAT EXCESSIVELY DRAINED SOILS DEVELOPED ON SAND DUNES AND DUNE SHEETS IN AEOLIAN MATERIAL FROM MIXED ROCKS. THEIR PROFILES HAVE THREE MAIN PARTS: (1) BROWN FINE SAND ABOUT 5 INCHES THICK; (2) YELLOWISH BROWN AND BROWN FINE SANDY LOAM ABOUT 10 INCHES THICK; AND (3) BROWN LOAMY FINE SAND TO 60 INCHES. ELEVATIONS ARE 4,200 TO 6,000 FEET. MAAT IS 47° TO 52° F. MAP IS 4 TO 6 INCHES. FFS IS 100 TO 120 DAYS. SLOPES ARE 2 TO 15 PERCENT.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHO	FRACT. >3 IN. (PCT)	PERCENT OF MATERIAL LESS THAN 3 IN. PASSING SIEVE 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-5	FS, LFS	SM	A-2	0	100	100	70-80	20-30	—	NP
5-15	FSL	SM, SC	A-4	0	100	95-100	70-80	35-50	20-25	NP-[illegible]
15-60	LFS, FS	SM	A-2	0	85-100	70-100	50-85	20-35	—	NP

DEPTH (IN.)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (pH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	CORROSIVITY STEEL	CORROSIVITY CONCRETE	EROSION FACTORS K	T	WIND EROD. GROUP
SAME DEPTH AS ABOVE	>20	0.07-0.09	6.6-7.3	<2	LOW	LOW	LOW	.15	5	1
	2.0-6.0	0.11-0.13	6.6-7.3	<2	LOW	MODERATE	LOW	.28		
	6.0-20	0.07-0.10	6.6-8.4	<2	LOW	HIGH	LOW	.17		

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INITIAL (IN)	TOTAL (IN)	HYD GRP	POTENTIAL FROST ACTION
NONE			>6.0			—		>60		—		B	LOW

SANITARY FACILITIES

	FOOTNOTES	
SEPTIC TANK ABSORPTION FIELDS	1	2-8%: SLIGHT 8-15%: MODERATE-SLOPE
SEWAGE LAGOONS	1	2-7%: SEVERE-SEEPAGE 7+%: SEVERE-SEEPAGE, SLOPE
SANITARY LANDFILL (TRENCH)	2	MODERATE-TOO SANDY
SANITARY LANDFILL (AREA)	2	2-8%: SLIGHT 8-15%: MODERATE-SLOPE
DAILY COVER FOR LANDFILL	1	2-8%: FAIR-TOO SANDY 8-15%: FAIR-TOO SANDY, SLOPE

COMMUNITY DEVELOPMENT

	FOOTNOTES	
SHALLOW EXCAVATIONS		SEVERE-CUTBANKS CAVE
DWELLINGS WITHOUT BASEMENTS		2-8%: SLIGHT 8-15%: MODERATE-SLOPE
DWELLINGS WITH BASEMENTS		2-8%: SLIGHT 8-15%: MODERATE-SLOPE
SMALL COMMERCIAL BUILDINGS		2-4%: SLIGHT 4-8%: MODERATE-SLOPE 8+%: SEVERE-SLOPE
LOCAL ROADS AND STREETS		2-8%: SLIGHT 8-15%: MODERATE-SLOPE

REGIONAL INTERPRETATIONS

FOOTNOTES	

SOURCE MATERIAL

	FOOTNOTES	
ROADFILL		GOOD
SAND		POOR-EXCESS FINES
GRAVEL		UNSUITED
TOPSOIL		POOR-TOO SANDY

WATER MANAGEMENT

	FOOTNOTES	
POND RESERVOIR AREA		SEEPAGE, SLOPE
EMBANKMENTS DIKES AND LEVEES		PIPING, SEEPAGE, LOW STRENGTH
EXCAVATED PONDS AQUIFER FED		NO WATER
DRAINAGE		COMPLEX SLOPE, CUTBANKS CAVE
IRRIGATION		DROUGHTY, COMPLEX SLOPE, SOIL BLOWING
TERRACES AND DIVERSIONS		ERODES EASILY, PIPING, TOO SANDY
GRASSED WATERWAYS		

UNIT NAME: MAYQUEEN
UNIT MODIFIER

(2) RECREATION

	Footnote	Recreation	Keying only		Footnote	Recreation
CAMP AREAS	FS: SEVERE-TOO SANDY, SOIL BLOWING; 2-8%: LES: MODERATE-TOO SANDY, SOIL BLOWING; 8-15%: LES: MODERATE-SLOPE, TOO SANDY, SOIL BLOWING		PLAYGD 321	PLAYGROUNDS		2-6%: SEVERE-TOO SANDY, SOIL BLOWING; 6+%: SEVERE-SLOPE, TOO SANDY, SOIL BLOWING
PICNIC AREAS	FS: SEVERE-TOO SANDY, SOIL BLOWING; 2-8%: LES: MODERATE-TOO SANDY, SOIL BLOWING; 8-15%: LES: MODERATE-SLOPE, TOO SANDY, SOIL BLOWING		PATHS 331	PATHS AND TRAILS		FS: SEVERE-TOO SANDY, SOIL BLOWING; LES: MODERATE-TOO SANDY, SOIL BLOWING

CAPABILITY AND PREDICTED YIELDS - CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

Class-determining phase	Capability NIRR	Capability IRR	Alfalfa hay (tons) NIRR	Alfalfa hay (tons) IRR	Barley (BU) NIRR	Barley (BU) IRR	Garlic (CWT) NIRR	Garlic (CWT) IRR	Onions (sacks) NIRR	Onions (sacks) IRR	Pasture (AUM) NIRR	Pasture (AUM) IRR	Potatoes, Irish (CWT) NIRR	Potatoes, Irish (CWT) IRR	Wheat (BU) NIRR	Wheat (BU) IRR
2-4%	7S	3S														
4-8%	7S	3E														
8-15%	7S	4E														

WOODLAND SUITABILITY

Class-determining phase	Ord sym	Erosion hazard	Equip. limit	Seedling mort'y.	Windth. hazard	Plant compet.	Important trees	Site index	Trees to plant
							NONE		

WIND BREAKS

Class-determining phase	Species	HT	Species	HT	Species	HT	Species	HT
ALL	SKUNKBUSH SUMAC	6	SIBERIAN ELM	32	ROCK MT. JUNIPER	12	JEFFREY PINE	

WILDLIFE HABITAT SUITABILITY

Class-determining phase	Grain & seed	Grass & legume	Wild herb.	Hardwd trees	Conifer plants	Shrubs	Wetland plants	Shallow water	Openland wildlife	Woodland wildlife	Wetland wildlife	Rangeland wildlife
NIRR	V. POOR	V. POOR	POOR	—	—	POOR	V. POOR	V. POOR	V. POOR	—	V. POOR	POOR
IRR	FAIR	FAIR	GOOD	—	—	GOOD	V. POOR	V. POOR	FAIR	—	V. POOR	GOOD

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

Common plant name	Plant symbol (NLSPN)	Percentage composition (dry weight) by class determining phase: ALL
INDIAN RICEGRASS	ORHY	20
GRAY HORSEBRUSH	TECA2	10
LITTLEAF HORSEBRUSH	TEGL	10
NEVADA EPHEDRA	EPNE	20
NEVADA DALEA	DAPO2	5
FOURWING SALTBUSH	ATCA2	25
WINTERFAT	EULA5	10

Potential production (lbs./ac. dry wt.)	ALL
Favorable years	500
Normal years	400
Unfavorable years	300

NOTES

A ESTIMATES BASED ON ENGINEERING TEST DATA OBTAINED FROM LYON COUNTY, NEVADA.
1 EXCESSIVE PERMEABILITY RATE MAY CAUSE POLLUTION OF GROUND WATER.
2 EXCESSIVE PERMEABILITY RATE NOT A LIMITATION DUE TO ARID CLIMATE.

UT0229

SOIL SURVEY INTERPRETATIONS

SOIL SERIES FILE

SHEPPARD SERIES

MLRA(S): 34, 35
REO. 4-75
TYPIC TORRIPSAMMENTS, MIXED, MESIC

THE SHEPPARD SERIES ARE VERY DEEP, SOMEWHAT EXCESSIVELY-DRAINED SOILS FORMED IN SANDY MATERIAL ON ROLLING UPLANDS UNDER GALLETA, SAND DROPSEED, AND SALTBUSH. MAST IS 54 TO 59 F. AAP IS 6 TO 8 INCHES. FFP IS 130 TO 150 DAYS. A TYPICAL PROFILE HAS A REDDISH-YELLOW FINE SAND SURFACE LAYER, 12 INCHES THICK. THE UNDERLYING LAYER IS REDDISH-YELLOW LOAMY FINE SAND TO 60 INCHES OR MORE. SLOPES ARE 3 TO 12 PERCENT.

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-12	FS	SM	A-2	0	100	100	[illegible]5-80	[illegible]-20	-	NP
12-60	LFS	SM	A-2	0	100	100	70-80	15-25	-	NP

DEPTH (IN.)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	CORROSIVITY STEEL	CORROSIVITY CONCRETE	EROSION FACTORS K	EROSION FACTORS T	WIND EROD. GROUP
0-12	6.0-20	0.05-0.07	7.5-9.0	<2	LOW	HIGH	MODERATE	.10	5	1
12-60	6.0-20	0.06-0.08	7.5-9.0	<2	LOW	HIGH	MODERATE	.10		

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		A	LOW

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	3-8%: SLIGHT 8+%: MODERATE-SLOPE
SEWAGE LAGOON AREAS	3-7%: SEVERE-SEEPAGE 7+%: SEVERE-SLOPE, SEEPAGE
SANITARY LANDFILL (TRENCH)	MODERATE-SEEPAGE, TOO SANDY
SANITARY LANDFILL (AREA)	MODERATE-SEEPAGE
DAILY COVER FOR LANDFILL	FAIR-TOO SANDY

SOURCE MATERIAL

ROADFILL	GOOD
SAND	POOR-EXCESS FINES
GRAVEL	UNSUITED
TOPSOIL	POOR-TOO SANDY

COMMUNITY DEVELOPMENT

SHALLOW EXCAVATIONS	SEVERE-CUTBANKS CAVE
DWELLINGS WITHOUT BASEMENTS	3-8%: SLIGHT 8+%: MODERATE-SLOPE
DWELLINGS WITH BASEMENTS	3-8%: SLIGHT 8+%: MODERATE-SLOPE
SMALL COMMERCIAL BUILDINGS	3-4%: SLIGHT 4-8%: MODERATE-SLOPE 8+%: SEVERE-SLOPE
LOCAL ROADS AND STREETS	3-8%: SLIGHT 8+%: MODERATE-SLOPE
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	

WATER MANAGEMENT

POND RESERVOIR AREA	SLOPE, SEEPAGE
EMBANKMENTS DIKES AND LEVEES	SEEPAGE, PIPING
EXCAVATED PONDS AQUIFIER FED	NO WATER
DRAINAGE	
IRRIGATION	
TERRACES AND DIVERSIONS	SLOPE, PIPING, TOO SANDY
GRASSED WATERWAYS	

REGIONAL INTERPRETATIONS

RECREATION

CAMP AREAS	SEVERE-TOO SANDY	PLAYGROUNDS	3-6%: SEVERE-TOO SANDY 6+%: SEVERE-SLOPE,TOO SANDY
PICNIC AREAS	SEVERE-TOO SANDY	PATHS AND TRAILS	SEVERE-TOO SANDY

CAPABILITY AND PREDICTED YIELDS -- CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
ALL	7S															

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS: EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	POTENTIAL PRODUCTIVITY: IMPORTANT TREES	SITE INDX	TREES TO PLANT
							NONE		

WINDBREAKS

CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS: GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	POTENTIAL AS HABITAT FOR: OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
ALL	V. POOR	V. POOR	POOR	-	V. POOR	POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	POOR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: ALL				
BLACK GRAMA	BOER4	5				
GALLETA	HIJA	8				
INDIAN RICEGRASS	ORHY	20				
NEEDLEANDTHREAD	STCO4	5				
SAND DROPSEED	SPCR	7				
OTHER PERENNIAL GRASSES	PPGG	5				
OTHER ANNUAL FORBS	AAFF	5				
OTHER PERENNIAL FORBS	PPFF	5				
BIG SAGEBRUSH	ARTR2	4				
BUD SAGEBRUSH	ARSPS	4				
FOURWING SALTBUSH	ATCA2	10				
SHADSCALE	ATCO	4				
BROOM SNAKEWEED	GUSA2	8				
OTHER SHRUBS	SSSS	10				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS		900				
NORMAL YEARS		625				
UNFAVORABLE YEARS		500				

FOOTNOTES

A ESTIMATES BASED ON ENGINEERING TEST DATA ON ONE PEDON FOR SAN JUAN COUNTY, UTAH.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS

MLRA(S) 28 | KIND OF UNIT SERIES | UNIT NAME UFFENS

STATE UTAH | RECORD NO. | AUTHOR(S) LHD | DATE 7-73 | REVISED | UNIT MODIFIER

CLASSIFICATION AND BRIEF SOIL DESCRIPTION

The Uffens series are deep, well drained soils formed in lake sediments on shorelines and beach bars, under shadscale, kochia, bud sagebrush, and Indian ricegrass. The mean annual air temperature is 49 to 52°F. The average snnual precipitation is 6 to 8 inches and the frost-free period is 115 to 120 days. The surface soil is light gray, strongly alkaline, silt loam about 1/2 inch thick. The subsoil is very pale brown, very strongly alkaline, sandy clay loam about 9 inches thick. The substratum is stratified, dominantly light gray sandy clay loam. Slopes are 0 to 5 percent.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHO	FRACT. >3 IN. (PCT)	PERCENT OF MATERIAL LESS THAN 3 IN. PASSING SIEVE 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-60	SCL	ML, CL	A-4, A-6	0	100	100	65-75	55-65	25-40	5-20

DEPTH (IN.)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (pH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	CORROSIVITY STEEL	CORROSIVITY CONCRETE	EROSION FACTORS K	EROSION FACTORS T	WIND EROD. GROUP
SAME DEPTH AS ABOVE	0.2-0.6	0.17-0.18	8.5-<9.1	15-30	MODERATE	HIGH	HIGH	.24	1	5

AWC = 10 TO 11 INCHES

WSC = 2.0 TO 3.5 INCHES

PERM = MODERATELY SLOW

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INITIAL (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENTIAL FROST ACTION
NONE			>6					>60		-		C	MODERATE

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	SEVERE - PERCS SLOWLY
SEWAGE LAGOONS	0-2%: SLIGHT 2-5%: MODERATE - SLOPE
SANITARY LANDFILL (TRENCH)	SLIGHT
SANITARY LANDFILL (AREA)	SLIGHT
DAILY COVER FOR LANDFILL	GOOD

COMMUNITY DEVELOPMENT

SHALLOW EXCAVATIONS	SLIGHT
DWELLINGS WITHOUT BASEMENTS	MODERATE - FROST ACTION, SHRINK-SWELL, LOW STRENGTH
DWELLINGS WITH BASEMENTS	MODERATE - SHRINK-SWELL, LOW STRENGTH
SMALL COMMERCIAL BUILDINGS	
LOCAL ROADS AND STREETS	SEVERE - LOW STRENGTH MODERATE - SHRINK-SWELL, FROST ACTION

REGIONAL INTERPRETATIONS

REGION	
REGION	

SOURCE MATERIAL

ROADFILL	SEVERE - LOW STRENGTH MODERATE - SHRINK-SWELL, FROST ACTION
SAND	UNSUITED - EXCESS FINES
GRAVEL	UNSUITED - EXCESS FINES
TOPSOIL	POOR - EXCESS SALT, EXCESS ALKALI FAIR - TOO CLAYEY

WATER MANAGEMENT

POND RESERVOIR AREA	SLOPE
EMBANKMENTS DIKES AND LEVEES	PIPING, LOW STRENGTH, SHRINK-SWELL
EXCAVATED PONDS AQUIFER FED	NO WATER
DRAINAGE	NOT NEEDED
IRRIGATION	EXCESS SALTS, EXCESS ALKALI
TERRACES AND DIVERSIONS	NOT NEEDED
GRASSED WATERWAYS	NOT NEEDED

Table B-8 (con.)

(2)

UNIT NAME: UFFENS

UNIT MODIFIER:

RECREATION

Control Word	No.		Footnote	Keying Only	No.		Footnote
CAMPS	401	CAMP AREAS	MODERATE - TOO CLAYEY	PLAYGD	321	PLAYGROUNDS	0-2%: MODERATE - TOO CLAYEY
	2				2		2-5%: MODERATE - SLOPE, TOO CLAYEY
	3				3		
	4				4		
	5				5		
PICNIC	311	PICNIC AREAS	MODERATE - TOO CLAYEY	PATHS	331	PATHS AND TRAILS	MODERATE - TOO CLAYEY
	2				2		
	3				3		
	4				4		
	5				5		

CAPABILITY AND PREDICTED YIELDS - CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

Control Word	No.	Class-Determining Phase	Capability NIRR	Capability IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
CROPHD	351																	
CROPS	341	ALL	7SDS															

WOODLAND SUITABILITY

Control Word	No.	Class-Determining Phase	Ord Sym	Erosion Hazard	Equip. Limit	Seedling Mort'y.	Windth. Hazard	Plant Compet.	Important Trees	Site Index	Trees to Plant
WOODS	361								NONE		

WIND BREAKS

Control Word	No.	Class-Determining Phase	Species	HT	Species	HT	Species	HT	Species	HT
WINDBK	381		NONE							

WILDLIFE HABITAT SUITABILITY

Control Word	No.	Class-Determining Phase	Grain & Seed	Grass & Legume	Wild Herb.	Hardwd Trees	Conifer Plants	Shrubs	Wetland Plants	Shallow Water	Openland Wildlife	Woodland Wildlife	Wetland Wildlife	Rangeland Wildlife
WILDLF	391	ALL	V. POOR	V. POOR	V. POOR	-	V. POOR	V. POOR	POOR	V. POOR	V. POOR	V. POOR	POOR	V. POOR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

Percentage composition (dry weight) by class determining phase

Control Word	No.	Common Plant Name	Plant Symbol (NLSPN)	ALL NIRR
PHASE	401			
PLANT	411	INDIAN RICEGRASS	ØRHY	20
	2	NEEDLEANDTHREAD	STCØ4	5
	3	GALLETA GRASS	HIJA	25
	4	SCARLET GLOBEMALLOW	SPCØ	3
	5	BUD SAGEBRUSH	ARSP	16
	6	SHADSCALE	ATCØ	10
	7	FINE DOUGLAS YELLOWBRUSH	CHVIE	5
	8	OTHER	UUUU	16

Control Word	No.	Potential Production (lbs./ac. dry wt.)	DESERT ALKALI BENCH
PRODUC	431	Favorable years	600
	2	Normal years	
	3	Unfavorable years	250

FOOTNOTES

Control Word	No.	Sym.	
NOTES	441	1	IF FOOTINGS ARE BELOW FROST LINE, FROST ACTION IS NOT A LIMITATION

SCS-SOILS-5
REV. MAY 1972
FILE CODE SOILS-12

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS

MLRA(S): 37 | KIND OF UNIT: Series | UNIT NAME: Huerfano

STATE: New Mexico | RECORD NO.: | AUTHOR(S): TLP | DATE: 2/76 | REVISED: | UNIT MODIFIER:

CLASSIFICATION AND BRIEF SOIL DESCRIPTION

The Huerfano series consists of shallow, moderately well drained soils. They formed in alluvium of shale and sandstone, origin on mesas, upland valley bottoms and valley side slopes. Slopes are 1 to 8 percent. Elevations range from 5600 to 6400 feet. M.A.P. is 6 to 10 inches. The M.A.T. is 51 to 55°F. Frost-free season is 140 to 160 days. Typically, the surface layer is 2 inches of light, yellowish brown silty clay loam. The subsoil is light yellowish brown and light olive brown clay to 14 inches where shale, bedrock is encountered.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHO	FRACT. >3 IN. (PCT)	Passing sieve 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-2	SICL, C	CL-ML, CH	A-7-6	0	100	100	90-100	75-95	40-65	15-35
2-14	C	CL, CH	A-7-6	0	100	100	90-100	75-95	45-65	20-40
14	WB									

DEPTH (IN.)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (pH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	CORROSIVITY STEEL	CORROSIVITY CONCRETE	EROSION FACTORS K	EROSION FACTORS T	WIND EROD. GROUP
SAME DEPTH AS ABOVE	0.06-0.2	0.13 - 0.19	7.9-9.0	4 - >16	Moderate	High	Low	.24	1	4
	<0.06-0.2	0.10 - 0.17	7.9-9.6	4 - >16	Moderate	High	Low	.32		

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INITIAL (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENTIAL FROST ACTION
None			> 6.0			--		10 - 20	Rippable	--		D	Low

SANITARY FACILITIES

	Footnote	
SEPTIC TANK ABSORPTION FIELDS	A	Severe - Percs slowly, depth to rock
SEWAGE LAGOONS		1 - 7%: Severe-depth to rock, 7 + %: Severe - depth to rock, slope
SANITARY LANDFILL (TRENCH)		Severe - depth to rock, too clayey
SANITARY LANDFILL (AREA)		Slight
DAILY COVER FOR LANDFILL		Poor - Area reclaim, too clayey

COMMUNITY DEVELOPMENT

	Footnote	
SHALLOW EXCAVATIONS	A	Severe - depth to rock, too clayey
DWELLINGS WITHOUT BASEMENTS		Severe - Depth to rock, low strength
DWELLINGS WITH BASEMENTS		Severe - Depth to rock, low strength
SMALL COMMERCIAL BUILDINGS		Severe - Depth to rock, low strength
LOCAL ROADS AND STREETS		Severe - Depth to rock, low strength

SOURCE MATERIAL

	Footnote	
ROADFILL	A	Poor - Area reclaim, low strength
SAND		Unsuited
GRAVEL		Unsuited
TOPSOIL		Poor - excess alkali, area reclaim, thin layer

WATER MANAGEMENT

	Footnote	
POND RESERVOIR AREA	A	1-2%: Depth to rock 2+%: Depth to rock, slope
EMBANKMENTS DIKES AND LEVEES		Depth to rock, compressible, low strength
EXCAVATED PONDS AQUIFER FED		No water
DRAINAGE		Depth to rock, excess alkali, percs slowly
IRRIGATION		Excess alkali percs slowly, slope
TERRACES AND DIVERSIONS		Depth to rock, percs slowly, slope
GRASSED WATERWAYS		Not needed

REGIONAL INTERPRETATIONS

FOOTNOTES	

Table B-8 (con.)

KEYING ONLY: RECORD NO. | CONTROL WORD | NO.

UNIT NAME: Huerfano

UNIT MODIFIER:

(2)

RECREATION

Control word	No.		Footnote	Rating	Keying only	No.		Footnote	Rating
CAMPS	301	CAMP AREAS	B	Moderate - percs slowly, too clayey	PLAYGD	321	PLAYGROUNDS		1-6%: Severe - depth to rock
	2					2			6+%: Severe - depth to rock, slope
	3					3			
	4					4			
	5					5			
PICNIC	311	PICNIC AREAS		Severe - dusty, too clayey	PATHS	331	PATHS AND TRAILS		Moderate - too clayey, dusty
	2					2			
	3					3			
	4					4			
	5					5			

CAPABILITY AND PREDICTED YIELDS - CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CROPHO 451, 2, 3

Control word	No.	CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
CROPS	341	All	7S	--														

WOODLAND SUITABILITY

Control word	No.	CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS: EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	POTENTIAL PRODUCTIVITY: IMPORTANT TREES	SITE INDEX	TREES TO PLANT
WOODS	361								None		

WIND BREAKS

Control word	No.	CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
WINDBK	381		None							

WILDLIFE HABITAT SUITABILITY

Control word	No.	Footnote	CLASS-DETERMINING PHASE	Potential for habitat elements: GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	Potential as habitat for: OPENLAND WILDLIFE	WOODLAND WILDLIFE	WETLAND WILDLIFE	RANGELAND WILDLIFE
WILDLF	391	C	All	V.Poor	V.Poor	V.Poor	--	--	V.Poor	Poor	V.Poor	V.Poor	--	V.Poor	V.Poor

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

Control word	No.	COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
PHASE	401							
PLANT	411							
	421							

Control word	No.	POTENTIAL PRODUCTION (LBS./AC. DRY WT)					
PRODUC	431	FAVORABLE YEARS					
	2	NORMAL YEARS					
	3	UNFAVORABLE YEARS					

FOOTNOTES

Control word	No.	SYM.	
NOTES	441	A	Ratings based on "Guide for Interpreting Engineering Uses of Soils," November 1971.
	2	B	Recreation ratings based on soils memorandum 69, October 1968.
	3	C	Wildlife ratings based on soils memorandum 74, January 1972.

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SCS-SOILS-5
REV. MAY 1972
FILE CODE SOILS-12

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS

KEYING ONLY		
RECORD NO.	CONTROL WORD	NO.
	MLRA	001
	STATE	011

MLRA(S) 27, 29 — KIND OF UNIT Series — UNIT NAME Stumble

STATE New Mexico — RECORD NO. 76 — AUTHOR(S) EAN — DATE 5/75 — REVISED — UNIT MODIFIER

CLASSIFICATION AND BRIEF SOIL DESCRIPTION

CLASS 021 / DESCR 031

Stumble series consist of deep somewhat excessively drained soil forming in mixed sandy alluvium on alluvial fans. Their profiles have three parts: (1) light brownish-gray loamy sand, surface layer 6 inches thick, (2) light brownish-gray loamy sand 23 inches thick; and (3) light brownish-gray gravelly loamy sand to 50 inches. Elevations are 4000 to 6000 feet. M.A.A.T. is 47 to 55°F. MAP is 4 to 8 inches. Slopes are 0 to 8 percent.

ESTIMATED SOIL PROPERTIES

FOOTNOTE

	DEPTH (IN)	USDA TEXTURE	UNIFIED	AASHO	FRACT. >3 IN. (PCT)	PERCENT OF MATERIAL LESS THAN 3 IN. PASSING SIEVE 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
PROP 041	0-6	LS, LFS	SM	A-2	0-5	85-100	85-100	55-75	15-25	<20	NP
2	0-6	FSL	SM	A-4	0-5	85-100	85-100	65-85	35-45	<25	NP
3	6-29	LS, LFS	SM	A-2	0-5	85-100	85-100	55-75	15-35	<20	NP
4	29-50	GR-LS, GR-LFS	SM	A-2	0-10	75-85	50-70	40-50	15-25	<20	NP
5											
6											

	DEPTH (IN.)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (pH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	CORROSIVITY STEEL	CORROSIVITY CONCRETE	EROSION FACTORS K	EROSION FACTORS T	WIND EROD. GROUP
PROP 051	SAME DEPTH AS ABOVE	6.0-20	0.06 - 0.02	6.6-8.4	< 2	Low	High	Low	.17	5	2
2		2.0-6.0	0.10 - 0.12	6.6-8.4	< 2	Low	High	Low	.28	5	3
3		6.0-20	0.06 - 0.08	7.9-8.4	< 4	Low	High	Moderate	.17		
4		6.0-20	0.04 - 0.06	7.9-9.0	< 8	Low	High	Moderate	.15		
5											
6											

	FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INITIAL (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENTIAL FROST ACTION
PROP 061	None			>6.0			-		> 60				A	Low

SANITARY FACILITIES

FOOTNOTES

SEPTIC 071	SEPTIC TANK ABSORPTION FIELDS		Slight
LAGOON 081	SEWAGE LAGOONS		0-7%: Severe - seepage 7+%: Severe - slope, seepage
TRENCH 091	SANITARY LANDFILL (TRENCH)	A	Moderate - too sandy
SANARE 101	SANITARY LANDFILL (AREA)	A	Slight
COVER 111	DAILY COVER FOR LANDFILL		Fair - too sandy

COMMUNITY DEVELOPMENT

FOOTNOTES

EXCAV 121	SHALLOW EXCAVATIONS	Severe - cutbanks cave
DWEL 131	DWELLINGS WITHOUT BASEMENTS	Slight
DWEL 141	DWELLINGS WITH BASEMENTS	Slight
BLDGS 151	SMALL COMMERCIAL BUILDINGS	0-4%: slight 4-8%: Moderate - slope
ROADS 161	LOCAL ROADS AND STREETS	Slight

REGIONAL INTERPRETATIONS

FOOTNOTES

REGION 171	
REGION 181	

SOURCE MATERIAL

KEYING ONLY — FOOTNOTES

FILL 191	ROADFILL	Good
SAND 201	SAND	Poor - excess fines
GRAVEL 211	GRAVEL	Unsuited - excess fines
SOIL 221	TOPSOIL	LS, LFS; Poor - too sandy FSL: Poor - thin layer

WATER MANAGEMENT

FOOTNOTES

PONDRS 231	POND RESERVOIR AREA	0-2% : seepage 2+%: seepage, slope
DIKES 241	EMBANKMENTS DIKES AND LEVEES	Seepage, piping
PONDAQ 251	EXCAVATED PONDS AQUIFER FED	No water
DRAIN 261	DRAINAGE	0-2% : Cutbanks cave 2+%: slope, cutbanks cave
IRRIG 271	IRRIGATION	0-2%: Droughty seepage, soil blowing 2+%: Droughty, slope, soil blowing
TERRAC 281	TERRACES AND DIVERSIONS	0-2%: Piping, soil blowing too sandy 2+%: Piping, soil blowing, slope
WATERW 291	GRASSED WATERWAYS	

(2)

UNIT NAME: Stumble

UNIT MODIFIER:

RECREATION

KEYING ONLY			FOOTNOTE	
CAMPS	301	CAMP AREAS		FSL: Slight
	2			LS, LFS: Severe - soil blowing
	3			
	4			
	5			
PICNIC	311	PICNIC AREAS		FSL: Slight
	2			LS, LFS: Severe - soil blowing
	3			
	4			
	5			

KEYING ONLY			FOOTNOTE	
PLAYGD	321	PLAYGROUNDS		0-2% FSL: Slight
	2			2-6% FSL: Moderate - slope
	3			6+% FSL: Severe - slope
	4			0-6% LS, LFS: Severe - soil blowing
	5			6+% LS, LFS: Severe - soil blowing, slope
PATHS	331	PATHS AND TRAILS		FSL : Slight
	2			LS, LFS: Moderate - too sandy
	3			
	4			
	5			

CAPABILITY AND PREDICTED YIELDS - CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

FOOTNOTE

KEYING ONLY		CLASS-DETERMINING PHASE	CAPABILITY															
			NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
CROPHD	451																	
	2																	
	3																	
CROPS	341	All	7S	3S														
	2																	
	3																	
	4																	
	5																	
	6																	
	7																	
	8																	
	9																	
	351																	
	2																	
	3																	

WOODLAND SUITABILITY

FOOTNOTE

KEYING ONLY		CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS: EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	POTENTIAL PRODUCTIVITY: IMPORTANT TREES	SITE INDEX	TREES TO PLANT
WOODS	361								None		
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	371										
	2										
	3										
	4										
	5										
	6										

WIND BREAKS

FOOTNOTE

KEYING ONLY		CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
WINDBK	381	All	Golden Willow	40	Russian-Olive	30	Athel	25	Rocky Mt. Juniper	25
	2									
	3									
	4									
	5									
	6									

WILDLIFE HABITAT SUITABILITY

FOOTNOTE

KEYING ONLY		CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS: GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	POTENTIAL AS HABITAT FOR: OPENLAND WILDLIFE	WOODLAND WILDLIFE	WETLAND WILDLIFE	RANGELAND WILDLIFE
WILDLF	391	JRR	Fair	Good	Good	Fair	--	Good	V.Poor	V.Poor	Fair	Fair	V.Poor	Good
	2	HIRR	--	--	Fair	--	--	Fair	--	--	--	--	--	Fair
	3													
	4													
	5													
	6													

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

FOOTNOTE

KEYING ONLY		COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: PP, FF	BS			
PHASE	401			LS	LFS, FSL			
	2							
PLANT	411	Bailly Grease wood	SAVEB	15	--			
	2	Fourwing saltbush	ATCA2	15	20			
	3	Winterfat	EULA5	10	5			
	4	Indian ricegrass	ORHY	40	20			
	5	Sand dropseed	SPCR	--	20			
	6	Desert needlegrass	STSP3	3				
	7							
	8	Littleleaf horsebrush	TEGL	2	10			
	9	Spiny Hopsage	GRSP	5	2			
	421	Dalia	DALEA	--	5			
	2	PPGG	PPGG	--	5			
	3	AAGG	AAGG	--	3			
	4	SSSS	SSSS	5	5			
	5	AAFF	AAFF	3	3			
	6	PPFF	PPFF	2	2			
PRODUC	431	POTENTIAL PRODUCTION (LBS./AC. DRY WT): FAVORABLE YEARS		600	400			
	2	NORMAL YEARS		400	300			
	3	UNFAVORABLE YEARS		250	250			

FOOTNOTES

KEYING ONLY		SYM.	
NOTES	441	A	Arid climate - permeability not used as criteria.
	2		
	3		
	4		
	5		
	6		
	7		

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REV. MAY 1972
FILE CODE SOILS-12

(1)

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL SURVEY INTERPRETATIONS

MLRA(S) 37 | KIND OF UNIT Series | UNIT NAME Laton

STATE New Mexico | RECORD NO. | AUTHOR(S) ADR, JER | DATE 2-76 | REVISED | UNIT MODIFIER

CLASSIFICATION AND BRIEF SOIL DESCRIPTION

The Laton series consists of deep, moderately well drained soils. They formed on upland valley bottoms and drainageways from alluvium of shale and sandstone origin. Slopes are from 0 to 2 percent. Elevations range from 5600 to 6400 feet. Mean annual precipitation ranges from 6 to 10 inches. Mean annual air temperatures range from 51 to 55 degrees F., and the frost-free season is 140 to 160 days. Typically, the surface layer is a grayish-brown clay loam about 3 inches thick. The subsoil is a grayish-brown clay about 20 inches thick. The substratum is a grayish-brown clay to 60 inches or more.

ESTIMATED SOIL PROPERTIES

Depth (in.)	USDA Texture	Unified	AASHO	Fract. >3 in. (pct)	Percent of material less than 3 in. passing sieve 4	10	40	200	Liquid limit	Plasticity index
0-3	CL	CL	A-6, A-7	0	100	100	90-100	70-80	35-45	10-20
0-3	SIC, C	CL, CH	A-7	0	100	100	90-100	80-95	40-65	15-30
3-60	SIC, C	CL, H	A-7	0	100	100	90-100	80-95	40-65	15-30

Depth (in.)	Permeability (in/hr)	Available water capacity (in/in)	Soil reaction (pH)	Salinity (mmhos/cm)	Shrink-swell potential	Corrosivity Steel	Corrosivity Concrete	Erosion factors K	T	Wind erod. group
Same depth as above	0.2 - 0.6	0.15 - 0.19	7.9-9.0	4-8	Moderate	High	High	.32	5	4L
	<0.06-0.2	0.13 - 0.19	7.9-9.0	4-8	High	High	High	.37	5	4L
	<0.06-0.2	0.13 - 0.19	7.9-9.0	4-8	High	High	High	.43		

Flooding Frequency	Duration	Months	High water table Depth (ft)	Kind	Months	Cemented pan Depth (in)	Hardness	Bedrock Depth (in)	Hardness	Subsidence Initial (in)	Total (in)	Hyd grp	Potential frost action
None			>6.0			-	-	> 60	-	-	-	D	Low

SANITARY FACILITIES

Septic tank absorption fields	A Severe - Percs slowly
Sewage lagoons	Slight
Sanitary landfill (trench)	Severe - too clayey
Sanitary landfill (area)	Slight
Daily cover for landfill	Poor - too clayey

COMMUNITY DEVELOPMENT

Shallow excavations	A Severe - too clayey
Dwellings without basements	Severe - shrink-swell, low strength
Dwellings with basements	Severe - Shrink-swell, low strength
Small commercial buildings	Severe - shrink-swell, low strength
Local roads and streets	Severe - shrink-swell, low strength

REGIONAL INTERPRETATIONS

REGION 171	
REGION 181	

SOURCE MATERIAL

Roadfill	A Poor - Shrink-Swell, Low strength
Sand	Unsuited
Gravel	Unsuited
Topsoil	Poor - excess alkali, too clayey

WATER MANAGEMENT

Pond reservoir area	A Favorable
Embankments dikes and levees	Compressible, low strength
Excavated ponds aquifer fed	No water
Drainage	Excess alkali, percs slowly
Irrigation	Percs slowly
Terraces and diversions	Percs slowly, too clayey
Grassed waterways	Not needed

Table B-8 (con.)

(2)

KEYING ONLY		
RECORD NO.	CONTROL WORD	NO.

UNIT NAME: Laton

UNIT MODIFIER:

RECREATION

KEYING ONLY			FOOTNOTE	
CAMPS	301, 2, 3, 4, 5	CAMP AREAS	B	Severe - percs slowly
PICNIC	311, 2, 3, 4, 5	PICNIC AREAS		Moderate - too clayey
PLAYGD	321, 2, 3, 4, 5	PLAYGROUNDS		Severe - percs slowly
PATHS	331, 2, 3, 4, 5	PATHS AND TRAILS		Moderate - too clayey

CAPABILITY AND PREDICTED YIELDS - CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

FOOTNOTE

CROPHD 451, 2, 3; CROPS 341, 2, 3, 4, 5, 6, 7, 8, 9, 351, 2, 3

CLASS-DETERMINING PHASE	CAPABILITY															
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
A11	7s	-														

WOODLAND SUITABILITY

FOOTNOTE

WOODS 361, 2, 3, 4, 5, 6, 7, 8, 9, 371, 2, 3, 4, 5, 6

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS: EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	POTENTIAL PRODUCTIVITY: IMPORTANT TREES	SITE INDEX	TREES TO PLANT
							None		

WIND BREAKS

FOOTNOTE

WINDBK 381, 2, 3, 4, 5, 6

CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
			None					

WILDLIFE HABITAT SUITABILITY

FOOTNOTE

WILDLF 391, 2, 3, 4, 5, 6

		POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	CLASS-DETERMINING PHASE	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLAND WILDLIFE	WOODLAND WILDLIFE	WETLAND WILDLIFE	RANGELAND WILDLIFE
C	A11	v.poor	v.poor	v.poor	--	--	poor	poor	poor	v.poor	-	poor	v.poor

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

FOOTNOTE

PHASE 401, 2; PLANT 411, 2, 3, 4, 5, 6, 7, 8, 9, 421, 2, 3, 4, 5, 6

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				

PRODUC 431, 2, 3

POTENTIAL PRODUCTION (LBS./AC. DRY WT.)
FAVORABLE YEARS
NORMAL YEARS
UNFAVORABLE YEARS

FOOTNOTES

NOTES 441, 2, 3, 4, 5, 6, 7

SYM.	
A	Ratings based on "Guide for Interpreting Engineering Uses of Soils." Nov. 1971.
B	Ratings based on Soils Memorandum 69. October 1968.
C	Ratings based on Soils Memorandum 74, January 1972.

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Table B-9

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bisti West
Location. Sec. 7 Twp. 23N Range 12W
1925'E, 850'N, SW Cor. - Profile 35
Climate: arid
Land Use: rangeland

Relief: nearly level to very slightly undulating
Elevation: 5885
Slope: Aspect: nearly level, SW
Vegetation: sparse native
Erosion: critical wind and water

Staniness: none
Drainage: somewhat poorly drained
Ground Water: none
Land Form: valley

Parent Material: alluvium
Soil Series: Turley
Soil Classification: 6s a 10
Profile Description By: R.G.Moore Date: 8-75

LAB NO.	DEPTH (inches)	PROFILE DESCRIPTION
180	0 - 12	Clay, dry, 10 YR 6/3, pale brown, moderate fine subangular blocky, hard, very firm, very sticky, and very plastic
181	12 - 24	Clay loam, dry, 10 YR 6/2, light brownish-gray, massive, hard, firm, slightly sticky and slightly plastic
182	24 - 48	Silt loam, dry, 10 YR 6/3, pale brown, massive, soft, friable, slightly sticky and slightly plastic
183	48 - 84	Loamy sand, dry, 10 YR 6/3, pale brown, single grain, loose, nonsticky and nonplastic
184	84 - 120	Fine sand, dry, 10 YR 6/3, pale brown, single grain, loose, nonsticky and nonplastic

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		180	181	182	183	184
DEPTH	ins.	0-12	12-24	24-48	48-84	84-120
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	51.0	35.6	32.2	76.8	73.6
Silt	(0.05-0.002 mm)	24.2	35.6	44.0	11.0	13.4
Clay	(<0.002 mm)	24.8	28.8	23.8	12.2	13.0
TEXTURAL CLASS (LAB.)		SCL	CL	L	SL	SL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(cm/hr)					
6^{th} hr		.17	.05	.04	.63	.62
24^{th} hr		.36	.07	.01	.64	1.08
SETTLING VOLUME	(ml)	32	35	41	[illegible]2	25
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		7.2	12.4	11.4	4.5	5.3
SOIL REACTION-pH						
Paste						
1:5 H_2O		7.9	7.8	8.0	7.9	8.1
0.01 M $CaCl_2$ (1:5)		7.6	6.8	7.2	7.3	7.3
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage		43.7	45.8	46.8	26.3	
EC_e @ 25°C	(mmhos/cm)	10.5	9.6	9.3	6.8	
Ca^{++} + Mg^{++}	(me/l)	28.5	27.7	28.2	23.6	
Mg^{++}	(me/l)					
Na^{+}	(me/l)	108.0	104.0	94.0	70.5	
K^{+}	(me/l)					
CO_3^{-}	(me/l)					
HCO_3^{-}	(me/l)					
Cl^{-}	(me/l)					
SO_4^{-}	(me/l)					
NO_3^{-}	(me/l)					
SAR		29	28	25	21	
Na	(me/100g)					
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	2.84	3.01	1.81	1.09	.84
Ca+Mg	(me/l)					
EXCHANGEABLE SODIUM	(percent)	20.7	12.1	15.2	12.0	
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	23.6	30.0	27.6	14.6	18.0
NaOAc@pH 8.2						
BORON	(mg/l)					

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Table B-9 (con.)

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bisti West
Location. Sec. 6 Twp. 23N Range 12W
2700'E, 1225'S, [illegible]-Profile 7
Climate: arid
Land Use: rangeland

Relief: nearly level, slightly undulating
Elevation: 6055
Slope: Aspect: very gently sloping, SW
Vegetation: good native
Erosion: moderate wind

Stoniness: none
Drainage: well drained
Ground Water: [illegible]
Land Form: [illegible]

Parent Material: alluvium with some eolian
Soil Series: Shiprock
Soil Classification: 1 vv / 1 3 2
Profile Description By: R.G. Moore Date: 8-75

LAB NO.	DEPTH (INCHES)	PROFILE DESCRIPTION
68	0 - 12	Loamy sand, dry, 10 YR 6/3, pale brown, fine granular, loose, nonsticky and nonplastic.
69	12 - 34	Sandy loam, dry, 10 YR 6/4, light yellowish-brown, massive, slightly hard, nonsticky and nonplastic.
70	34 - 48	Sandy loam, dry, 10 YR 6/3, pale brown, massive, slightly hard, slightly sticky, nonplastic.
71	48 - 90	Loamy sand, dry, 10 YR 6/4, light yellowish-brown, fine granular, slightly hard, nonsticky and nonplastic.
72	90 - 108	Sand, dry, 10 YR 6/3, pale brown, single grain, loose, nonsticky and nonplastic. Sand and some gravel from 108 - 180.

LABORATORY DESCRIPTION

DETERMINATION	Units	DATA				
LABORATORY NUMBER		68	69	70	71	72
DEPTH	in.	0 - 12	12 - 34	34 - 48	48 - 90	90 - 108
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	75.4	75.2	72.4	89.2	95.0
Silt	(0.05-0.002 mm)	14.6	14.8	13.4	5.4	2.6
Clay	(< 0.002 mm)	10.0	10.0	14.2	5.4	2.4
TEXTURAL CLASS (LAB)		SL	SL	SL	S	S
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(cm/hr)					
6th hr		1.76	.96	.34	2.34	4.08
24th hr		.53	.81	.42	.70	1.27
SETTLING VOLUME	(ml)	14	16	19	16	14
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		4.1	4.6	4.7	2.1	1.1
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.5	8.7	9.1	8.5	9.2
0.01 M $CaCl_2$ (1:5)		7.4	7.3	7.6	6.6	7.4
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage					22.7	20.9
EC_e @ 25°C	(mmhos/cm)				4.8	1.8
Ca^{++} + Mg^{++}	(me/l)				10.0	4.0
Mg^{++}	(me/l)					
Na^+	(me/l)				34.5	15.6
K^+	(me/l)					
CO_3^-	(me/l)					
HCO_3^-	(me/l)					
Cl^-	(me/l)					
SO_4^-	(me/l)					
NO_3^-	(me/l)					
SAR					15	11
Na	(me/100g)					
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	.06	.07	.21	.58	.18
Ca+Mg	(me/l)					
EXCHANGEABLE SODIUM	(percent)				3.2	8.7
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	12.0	13.6	9.6	6.8	5.4
NaOAc@pH 8.2						
BORON	(mg/l)					

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Table B-9 (con.)

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bisti West
Location. Sec. 17 Twp. 23N Range 12W
35 'N, 250'W, SE Cor. - Profile 58
Climate: arid
Land Use: rangeland

Relief: gently sloping
Elevation: 5940
Slope: Aspect: gently sloping N
Vegetation: fair native
Erosion: moderate wind

Stoniness: none
Drainage: somewhat poorly drained
Ground Water: none
Land Form: side slope on sandy ridge

Parent Material: eolian and alluvium
Soil Series: Doak
Soil Classification: 3s / 3 7
Profile Description By: R.G.Moore Date: 8/75

LAB NO.	DEPTH (inches)	PROFILE DESCRIPTION
275	0 - 6	Loamy fine sand, dry, 10 YR 5/3, brown, fine granular, loose, nonsticky, and nonplastic
276	6 - 28	Clay loam, dry, 10 YR 6/2, light brownish-gray, median subangular blocky, hard, moderate sticky, and moderate plastic
277	28 - 38	Clay loam, dry, 5 YR 6/3, light reddish-brown, coarse and median hard, slightly sticky, and slightly plastic
278	38 - 48	Sandy loam, dry, 5 YR 6/3, light reddish-brown, fine granular, slightly hard, nonsticky, and nonplastic
279	48 - 64	Clay loam, dry, 10 YR 6/2, light brownish-gray, median angular blocky, moderate hard, moderate sticky, and moderate plastic
280	64 - 80	Loamy sand, dry, 10 YR 6/3, pale brown, single grain, slightly hard, nonsticky, and nonplastic, 80-86, sand, no sample
281	86 - 120	Loam, dry, 10 YR 6/4, light yellowish-brown, fine granular, moderate hard, moderate sticky, and moderate plastic

LABORATORY DESCRIPTION

DETERMINATION		DATA						
LABORATORY NUMBER		275	276	277	278	279	280	281
DEPTH	in.	0-6	6-28	28-38	38-48	48-64	64-80	86-120
PARTICLE SIZE ANALYSIS	(percent)							
Very Coarse Sand	(2.0-1.0 mm)							
Coarse Sand	(1.0-0.5 mm)							
Medium Sand	(0.5-0.25 mm)							
Fine Sand	(0.25-0.10 mm)							
Very Fine Sand	(0.10-0.05 mm)							
Total Sand	(2.0-0.05 mm)	85.0	57.8	56.2	73.6	52.4	73.0	70.2
Silt	(0.05-0.002 mm)	5.8	13.6	15.4	9.0	24.4	8.6	14.4
Clay	(< 0.002 mm)	9.2	28.6	28.4	12.4	23.2	18.4	15.4
TEXTURAL CLASS (LAB)		LS	SCL	SCL	SL	SCL	SL	SL
BULK DENSITY	(g/cm^3)							
HYDRAULIC CONDUCTIVITY	(cm / hr)							
6th hr		6.12	.04	0	0	0	0	.17
24th hr		1.20	.05	0	0	0	0	.07
SETTLING VOLUME	(ml)	17	45	100	80	90	70	34
MOISTURE RETENTION	(percent)							
1/10 bar								
1/3 bar								
15 bar		6.5	10.6	11.4	12.1	6.4	8.0	7.5
SOIL REACTION-pH								
Paste								
1:5 H_2O		8.9	8.1	8.5	9.3	9.0	9.0	8.8
0.01 M $CaCl_2$ (1:5)		7.4	7.7	7.6	7.7	7.8	7.7	7.0
ORGANIC CARBON	(percent)							
AVAILABLE PHOSPHORUS	(ppm)							
$CaCO_3$ EQUIVALENT	(percent)							
GYPSUM REQUIREMENT	(me/100g)							
SATURATION EXTRACT								
Saturation Percentage		28.2	43.5	41.7	31.8	46.1	37.6	35.2
EC_e @ 25°C	(mmhos/cm)	0.4	8.2	8.0	5.3	5.6	4.5	6.3
Ca^{++} + Mg^{++}	(me/l)	1.8	22.0	24.0	6.8	9.2	7.2	22.0
Mg^{++}	(me/l)							
Na^+	(me/l)	1.5	95.0	100.0	55.0	55.0	50.0	65.0
K^+	(me/l)							
CO_3^-	(me/l)							
HCO_3^-	(me/l)							
Cl^-	(me/l)							
SO_4^-	(me/l)							
NO_3^-	(me/l)							
SAR		1.6	29	29	30	26	26	19
Na	(me/100g)							
Ca+Mg	(me/100g)							
1:5 EXTRACT								
EC_5 @ 25°C	(mmhos/cm)	.08	2.85	1.12	.48	.73	.50	.58
Ca+Mg	(me/l)							
EXCHANGEABLE SODIUM	(percent)							
ACIDITY								
IN KCl exchange acidity								
Total	(me/100g)							
Al^{+++}	(me/100g)							
CATION EXCHANGE CAPACITY	(me/100g)	11.8	25.4	29.6	18.8	45.6	27.8	
NaOAc@pH 8.2								
BORON	(mg/l)							

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Table B-9 (con.)

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bisti West
Location. Sec. 8 Twp. 23N Range 12W
1550'W, 1850'S, NE Cor. - Profile 70
Climate: arid
Land Use: rangeland

Relief: moderately undulating and rolling
Elevation: 5960
Slope: Aspect: complex - SE
Vegetation: moderately good native
Erosion: moderate wind

Stoniness: None
Drainage: excessively drained
Ground Water: None
Land Form: mesa

Parent Material: alluvium and eolian
Soil Series: Mayqueen
Soil Classification: 3s w $^{3}10$
Profile Description By: R.G. Moore Date: 8/75

LAB NO.	DEPTH (inches)	PROFILE DESCRIPTION
	0-3	Loamy fine sand, dry, 10 YR 5/3, brown, single grain, loose, nonsticky, and nonplastic
	3-12	Fine sand loam, dry, 7.5 YR 5/4, brown, weak blocky, slightly hard, nonsticky, and nonplastic
	12-24	Loamy fine sand, dry, 10 YR 6/4, light yellowish brown, single grain, loose, nonsticky, and nonplastic
	24-38	Fine sand, dry, 10 YR 6/4, light yellowish brown, single grain, loose, nonsticky, and nonplastic
	38-60	Loamy sand, 10 YR 6/4, light yellowish brown, single grain, loose, nonsticky, and nonplastic

LABORATORY DESCRIPTION

DETERMINATION		DATA
LABORATORY NUMBER		No Laboratory Data
DEPTH	(cm)	
PARTICLE SIZE ANALYSIS	(percent)	
Very Coarse Sand	(2.0-1.0 mm)	
Coarse Sand	(1.0-0.5 mm)	
Medium Sand	(0.5-0.25 mm)	
Fine Sand	(0.25-0.10 mm)	
Very Fine Sand	(0.10-0.05 mm)	
Total Sand	(2.0-0.05 mm)	
Silt	(0.05-0.002 mm)	
Clay	(< 0.002 mm)	
TEXTURAL CLASS (LAB)		
BULK DENSITY	(g/cm^3)	
HYDRAULIC CONDUCTIVITY	(cm/hr)	
6^{th} hr		
24^{th} hr		
SETTLING VOLUME	(ml)	
MOISTURE RETENTION	(percent)	
1/10 bar		
1/3 bar		
15 bar		
SOIL REACTION-pH		
Paste		
1:5 H_2O		
1:2 0.01 M $CaCl_2$		
ORGANIC CARBON	(percent)	
AVAILABLE PHOSPHORUS	(ppm)	
$CaCO_3$ EQUIVALENT	(percent)	
GYPSUM REQUIREMENT	(me/100g)	
SATURATION EXTRACT		
Saturation Percentage		
EC_e @ 25°C	(mmhos/cm)	
Ca^{++}	(me/l)	
Mg^{++}	(me/l)	
Na^+	(me/l)	
K^+	(me/l)	
CO_3^-	(me/l)	
HCO_3^-	(me/l)	
Cl^-	(me/l)	
SO_4^-	(me/l)	
NO_3^-	(me/l)	
SAR	(me/l)	
Na	(me/100g)	
Ca+Mg	(me/100g)	
1:5 EXTRACT		
EC_5 @ 25°C	(mmhos/cm)	
Ca+Mg	(me/l)	
EXCHANGEABLE SODIUM	(percent)	
ACIDITY		
IN KCl exchange acidity		
Total	(me/100g)	
Al^{+++}	(me/100g)	
CATION EXCHANGE CAPACITY	(me/100g)	
NaOAc@pH 8.2		
BORON	(mg/l)	

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Table B-9 (con.)

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bisti West
Location. Sec. 7 Twp. 23N Range 12W
?00'E, 125'S, NW Cor.-Profile 23
Climate: arid
Land Use: rangeland

Relief: slightly to moderately undulating
Elevation: 5910
Slope: Aspect: nearly level, SW
Vegetation: ?ood native
Erosion: moderate wind

Stoniness: none
Drainage: somewhat excessively drained
Ground Water: none
Land Form: Sandy ridge in valley

Parent Material: eolian material over alluvium
Soil Series: Sheppard
Soil Classification: 3? vp / $3_7 3_3$
Profile Description By: R.G. Moore Date: 8-75

LAB NO.	DEPTH (INCHES)	PROFILE DESCRIPTION
133	0 - 12	Fine sand, dry, 10 YR 6/4, light yellowish-brown, single grain, loose, nonsticky and nonplastic
134	12 - 48	Fine sand, dry, 10 YR 6/4, light yellowish-brown, single grain, slightly compact, nonsticky and nonplastic
135	48 - 84	Fine sand, dry, 10 YR 6/4, light yellowish-brown, single grain, loose, nonsticky and nonplastic
136	84 - 108	Loamy fine sand, dry, 10 YR 6/3, pale brown, single grain, slightly compact, nonsticky and nonplastic
137	108 - 120	Sandy clay, dry, 10 YR 5/2, grayish-brown, fine angular blocky, moderate hard, very sticky, and slightly plastic

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		133	134	135	136	137
DEPTH	(ins.)	0 - 12	12 - 48	48 - 84	84 - 108	108 - 120
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	92.6	92.8	92.0	87.6	62.6
Silt	(0.05-0.002 mm)	3.2	3.0	3.8	4.4	12.0
Clay	(<0.002 mm)	4.2	4.2	4.2	8.0	25.4
TEXTURAL CLASS (LAB.)		S	S	S	S	SCL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(cm/hr)					
6^{th} hr		8.00	.04	.03	0	0
24^{th} hr		1.98	.03	.01	0	0
SETTLING VOLUME	(ml)	13	31	33	65	300
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		2.4	2.6	2.2	3.8	13.2
SOIL REACTION-pH						
Paste						
1:5 H_2O		7.9	9.4	9.4	9.5	8.1
~~KCl~~ 0.01 M $CaCl_2$ (1:5)		6.2	6.9	7.1	7.5	7.6
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage						130.5
EC_e @ 25°C	(mmhos/cm)					7.4
Ca^{++} + Mg^{++}	(me/l)					25.6
Mg^{++}	(me/l)					
Na^+	(me/l)					69.0
K^+	(me/l)					
CO_3^-	(me/l)					
HCO_3^-	(me/l)					
Cl^-	(me/l)					
SO_4^-	(me/l)					
NO_3^-	(me/l)					
SAR						19
Na	(me/100g)					
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	.06	.23	.29	.40	1.55
Ca+Mg	(me/l)					
EXCHANGEABLE SODIUM	(percent)					2.8
ACIDITY						
1N KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	7.6	7.6	14.8		27.6
NaOAc@pH 8.2						
BORON	(mg/l)					

GPO 835-766

7-2006A (1-76)
Bureau of Reclamation

Table B-9 (con.)

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bisti West
Location. Sec. 7 Twp. 23N Range 12W
300'W, 2400'N, SE Cor. - Profile 44
Climate: arid
Land Use: rangeland

Relief: nearly level
Elevation: 5920
Slope: Aspect: nearly level - SW
Vegetation: none or very sparse native
Erosion: severe wind and water

Stoniness: none
Drainage: poorly drained
Ground Water: none
Land Form: valley

Parent Material: alluvium
Soil Series: Uffens
Soil Classification: 6s a / 6_{10}
Profile Description By: R.G. Moore Date: 8/75

LAB NO.	DEPTH (inches)	PROFILE DESCRIPTION
214	0-12	Silty clay, dry, 10 YR 6/3, pale brown, fine granular, slightly hard, moderate sticky, and moderate plastic
215	12-44	Clay loam, dry, 10 YR 6/3, pale brown, fine granular, soft, moderate sticky, and moderate plastic
216	44-72	Very fine sand, dry, 10 YR 6/3, pale brown, single grain, loose, nonsticky, and nonplastic
217	72-94	Sand, dry, 10 YR 6/4, light yellowish brown, single grain, loose, nonsticky, and nonplastic
218	94-108	Loamy sand, dry, 10 YR 6/3, pale brown, single grain, slightly compact, nonsticky, and nonplastic
	108-120	Sand, dry, 10 YR 6/3, pale brown, single grain, loose, nonsticky, and nonplastic

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		214	215	216	217	218
DEPTH	(inches)	0-12	12-44	44-72	72-94	94-108
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	33.6	49.8	89.4	93.4	71.2
Silt	(0.05-0.002 mm)	30.2	27.0	8.4	3.4	19.0
Clay	(< 0.002 mm)	36.2	23.2	2.2	3.2	9.8
TEXTURAL CLASS (LAB)		CL	SCL	S	S	SL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(cm/hr)					
6^{th} hr		0	0	0	0	.40
24^{th} hr		0	0	0	0	.27
SETTLING VOLUME	(ml)	65	50	55	105	
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		16.8	8.9	3.4	3.2	5.6
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.2	9.1	9.1	9.5	8.3
1:5 0.01 M $CaCl_2$		7.8	7.7	7.7	7.8	7.7
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage		61.9	38.9		28.8	33.0
EC_e @ 25°C	(mmhos/cm)	5.6	3.8		1.6	7.4
Ca^{++} + Mg^{++}	(me/l)	15.4	4.6		1.2	22.9
Mg^{++}	(me/l)					
Na^+	(me/l)	57.0	40.5		16.5	73.5
K^+	(me/l)					
CO_3^-	(me/l)					
HCO_3^-	(me/l)					
Cl^-	(me/l)					
SO_4^-	(me/l)					
NO_3^-	(me/l)					
SAR		21	27		21	22
Na	(me/100g)					
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	1.08	.55	.31	.24	1.24
Ca+Mg	(me/l)					
EXCHANGEABLE SODIUM	(percent)	11.6	15.8		22.6	11.8
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	42.0	21.6	8.2	7.6	15.0
NaOAc@pH 8.2						
BORON	(mg/l)					

GPO 833-796

7-2006A (6-76)
Bureau of Reclamation

Table B-9 (con.)

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bisti West
Location. Sec. 6 Twp. 23N Range 12W
4_0'E, 400'N, SW Cor.-Profile 22
Climate: arid
Land Use: rangeland

Relief: slightly sloping
Elevation: 5915
Slope: Aspect: slightly sloping, SW
Vegetation: very sparse to none - native
Erosion: severe water and wind

Stoniness: none
Drainage: very poorly drained
Ground Water: none
Land Form: upland valley slopes

Parent Material: local alluvium over residual
Soil Series: Huerfano
Soil Classification: 5a a / 6I
Profile Description By: R.G. Moore Date: 8-75

LAB NO.	DEPTH (INCHES)	PROFILE DESCRIPTION
130	0 - 12	Clay, dry, 10 YR 5/2, grayish-brown, fine subangular blocky, very hard, very sticky, and very plastic
131	12 - 24	Shale, dry, 10 YR 2/1, black, fine subangular blocky, very hard, very sticky and plastic
132	24 - 36	Shale, dry, 5 Y 3/2, dark olive gray, fine subangular blocky, very hard, very sticky, and very plastic

LABORATORY DESCRIPTION

DETERMINATION		DATA		
LABORATORY NUMBER		130	131	132
DEPTH	(ins)	0 - 12	12 - 24	24 - 36
PARTICLE SIZE ANALYSIS	(percent)			
Very Coarse Sand	(2.0-1.0 mm)			
Coarse Sand	(1.0-0.5 mm)			
Medium Sand	(0.5-0.25 mm)			
Fine Sand	(0.25-0.10 mm)			
Very Fine Sand	(0.10-0.05 mm)			
Total Sand	(2.0-0.05 mm)	18.6	49.4	7.6
Silt	(0.05-0.002 mm)	51.4	25.0	44.2
Clay	(< 0.002 mm)	30.0	25.6	48.2
TEXTURAL CLASS (LAB.)		SiCL	SCL	SiC
BULK DENSITY	(g/cm^3)			
HYDRAULIC CONDUCTIVITY	(cm/hr)			
6^{th} hr		0	.07	0
24^{th} hr		0	.07	0
SETTLING VOLUME	(ml)	65	200	43
MOISTURE RETENTION	(percent)			
1/10 bar				
1/3 bar				
15 bar		21.4	19.4	33.6
SOIL REACTION-pH				
Paste				
1:5 H_2O		7.8	6.4	7.6
~~xxx~~ 0.01 M $CaCl_2$ (1:5)		7.6	5.0	6.6
ORGANIC CARBON	(percent)			
AVAILABLE PHOSPHORUS	(ppm)			
$CaCO_3$ EQUIVALENT	(percent)			
GYPSUM REQUIREMENT	(me/100g)			
SATURATION EXTRACT				
Saturation Percentage		65.5	60.0	89.8
EC_e @ 25°C	(mmhos/cm)	12.0	12.6	5.6
Ca^{++} + Mg^{++}	(me/l)	28.2	27.1	5.0
Mg^{++}	(me/l)			
Na^+	(me/l)	80.0	88.0	57.0
K^+	(me/l)			
CO_3^-	(me/l)			
HCO_3^-	(me/l)			
Cl^-	(me/l)			
SO_4^-	(me/l)			
NO_3^-	(me/l)			
SAR		21	24	36
Na	(me/100g)			
Ca+Mg	(me/100g)			
1:5 EXTRACT				
EC_5 @ 25°C	(mmhos/cm)	2.14	2.71	.74
Ca+Mg	(me/l)			
EXCHANGEABLE SODIUM	(percent)	32.2	35.0	
ACIDITY				
IN KCl exchange acidity				
Total	(me/100g)			
Al^{+++}	(me/100g)			
CATION EXCHANGE CAPACITY	(me/100g)	52.0	42.0	
NaOAc@pH 8.2				
BORON	(mg/l)			

GPO 835-758

7-2006A (1-76)
Bureau of Reclamation

Table B-9 (con.)

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bisti West
Location. Sec. 6 Twp. 23N Range 12W
2500'E, 75'N, SW Cor.-Profile 25
Climate: arid
Land Use: rangeland

Relief: nearly level
Elevation: 5900
Slope: Aspect: very gentle, SW
Vegetation: sparse native
Erosion: severe wind and water

Stoniness: none
Drainage: poorly drained
Ground Water: none
Land Form: valley

Parent Material: alluvium
Soil Series: Stumble
Soil Classification: 6s a / 6$_{10}$
Profile Description By: R.G.Moore Date: 8-75

LAB NO.	DEPTH (inches)	PROFILE DESCRIPTION
142	0 - 12	Loamy fine sand, dry, 10 YR 6/4, light yellowish-brown, single grain, soft, very friable, nonsticky and nonplastic
143	12 - 24	Loamy sand, dry, 10 YR 6/4, light yellowish-brown, single grain, soft, loose, nonsticky and nonplastic
144	24 - 66	Fine sand, dry, 10 YR 6/4, light yellowish-brown, single grain, soft, loose, nonsticky and nonplastic
145	66 - 90	Fine sand, dry, 7.5 YR 6/4, light brown, single grain, soft, loose, nonsticky and nonplastic
146	90 - 120	Silty clay, dry, 7.5 YR 4/2, brown, strong fine angular blocky, hard, firm, sticky and plastic

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		142	143	144	145	146
DEPTH	(in.)	0 - 12	12-24	24-66	66-90	90-120
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	70.8	83.6	88.8	83.6	51.4
Silt	(0.05-0.002 mm)	16.2	6.2	5.0	8.2	20.4
Clay	(<0.002 mm)	13.0	10.2	6.2	8.2	28.2
TEXTURAL CLASS (LAB)		SL	LS	S	LS	SCL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(cm/hr)					
6th hr		.38	.04	0	0	0
24th hr		.33	.002	0	0	.008
SETTLING VOLUME	(ml)	29	38	38	70	70
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		5.7	4.5	3.0	3.5	11.5
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.5	8.8	9.5	9.4	8.3
0.01 M $CaCl_2$ (1:5)		7.3	7.5	7.6	7.7	7.7
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage		34.5	31.3		30.6	47.4
EC_e @ 25°C	(mmhos/cm)	8.6	9.2		7.2	6.6
Ca^{++}+ Mg^{++}	(me/l)	23.3	23.4		15.4	28.6
Mg^{++}	(me/l)					
Na^+	(me/l)	82.5	76.0		69.0	64.0
K^+	(me/l)					
CO_3^-	(me/l)					
HCO_3^-	(me/l)					
Cl^-	(me/l)					
SO_4^-	(me/l)					
NO_3^-	(me/l)					
SAR		24	22		25	17
Na	(me/100g)					
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	1.44	1.05	.46	.62	.48
Ca+Mg	(me/l)					
EXCHANGEABLE SODIUM	(percent)	19.2			9.3	22.5
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	16.4		13.0	7.4	31.0
NaOAc@pH 8.2						
BORON	(mg/l)					

GPO 833-796

7-2006A (6-76)
Bureau of Reclamation

Table B-9 (con.)

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bisti West
Location. Sec. 7 Twp. 23N Range 12W
1[illegible]10'E, 1800'S, NW Cor.-Profile 38
Climate: arid
Land Use: rangeland

Relief: nearly level
Elevation: 5885
Slope: Aspect: very gentle, SW
Vegetation: very sparse-native
Erosion: critical water and wind

Stoniness: none
Drainage: poorly drained
Ground Water: [illegible]
Land Form: valley

Parent Material: Alluvium
Soil Series: Laton
Soil Classification: 6s a / 6_{10}
Profile Description By: R.G. Moore Date: 8-75

LAB NO.	DEPTH (INCHES)	PROFILE DESCRIPTION
194	0 - 12	Clay loam, dry, 10 YR 5/3, brown, fine granular to weak subangular blocky, moderate hard, moderately sticky, and slightly plastic
195	12 - 24	Clay, dry, 2.5 Y 5/2, grayish-brown, fine granular, moderate friable, very sticky, and very plastic
196	24 - 48	Clay, dry, 2.5 Y 4/2, dark grayish-brown, massive, extremely hard, very sticky, and very plastic
197	48 - 68	Clay, dry, 2.5 Y 4/2, dark grayish-brown, massive, extremely hard, very sticky, and very plastic
198	68 - 120	Loamy find sand, dry 10 YR 5/3, brown, single grain, very friable, nonsticky, and nonplastic

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		194	195	196	197	198
DEPTH	(ins)	0 - 12	12 - 24	24 - 48	48 - 68	68 - 120
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	47.2	21.6	13.6	37.6	46.6
Silt	(0.05-0.002 mm)	25.6	26.4	27.2	26.8	34.6
Clay	(< 0.002 mm)	27.2	52.0	59.2	35.6	18.8
TEXTURAL CLASS (LAB.)		SCL	C	C	CL	L
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(cm / hr)					
6th hr		0	0	0	0	0
24th hr		0	0	0	0	0
SETTLING VOLUME	(ml)	55	55	250	60	100
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		12.5	19.1	23.0	16.5	8.6
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.3	7.8	8.5	7.8	9.3
0.01 M $CaCl_2$ (1:5)		7.6	7.7	7.8	7.7	7.9
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me / 100g)					
SATURATION EXTRACT						
Saturation Percentage		48.8	71.0	95.5		
EC_e @ 25°C	(mmhos/cm)	6.94	7.40	7.40		
Ca^{++} + Mg^{++}	(me / l)	23.6	24.0	20.5		
Mg^{++}	(me / l)					
Na^+	(me / l)	70.5	75.0	75.0		
K^+	(me / l)					
CO_3^-	(me / l)					
HCO_3^-	(me / l)					
Cl^-	(me / l)					
SO_4^-	(me / l)					
NO_3^-	(me / l)					
SAR		21	22	23		
Na	(me / 100g)					
Ca+Mg	(me / 100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	1.38	3.64	1.40	3.03	.40
Ca+Mg	(me / l)					
EXCHANGEABLE SODIUM	(percent)	10.7	13.0	11.9		
ACIDITY						
1N KCl exchange acidity						
Total	(me / 100g)					
Al^{+++}	(me / 100g)					
CATION EXCHANGE CAPACITY	(me / 100g)	29.6	43.6	54.0	46.0	25.0
NaOAc@pH 8.2						
BORON	(mg / l)					

GPO 835-786

Form 7310–12
(May 1973)

Table B-10
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By: R G MOORE | Date: 8-15

Location 1925'E, 850'N, SW COR. SEC. 7 T23N, R.12W
MU-7010 PROFILE 35

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. $\boxed{9}$ 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed $\boxed{12}$ 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 $\boxed{5}$ 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 $\boxed{8}$ 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		PRESENT SSF = 35	÷ 57 X 100 = 61		

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Form 7310-12
(May 1973)

Table B-10 (con.)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By: R G MOORE | Date: 9-75

Location 2700'E, 1225'S, NW COR. SEC 6, T23N, R12W
MU-7003 PROFILE 7

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 $\boxed{7}$ 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 $\boxed{8}$ 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		PRESENT SSF = 15 ÷	28 X 100 = 54		

Erosion Condition Classes: *Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

(Instructions on reverse)

Form 7310–12
(May 1973)

Table B-10 (con.)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

By	Date
R G MOORE	8-75
Location 350'N, 250'W, SE COR., SEC. 17 T23N, R12W MU-7004 PROFILE 58	
Treatment affecting the SSF	

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 $\boxed{5}$	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed $\boxed{10}$ 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 $\boxed{5}$ 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15
SITUATION	TOTAL				
		PRESENT SSF = 20	÷ 43 X 100 = 47		

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Form 7310-12
(May 1973)

Table B-10 (con.)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By RG MOORE | Date 8-75

Location 1550'W, 1850'S, NE COR. SEC. 8 T23N, R12W

MU-7007 PROFILE 70

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. $\boxed{6}$ 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed $\boxed{10}$ 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals, less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		PRESENT SSF = 16 ÷ 28	X100 = 57		

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

7310-12
1973)

Table B-10 (con.)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By	Date
E G MOORE	8-75
Location 800'E, 125'S, NW COR. SEC. 7 T23N. R.12W MU-7008 PROFILE 23	
Treatment affecting the SSF	

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 $\boxed{5}$	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed $\boxed{10}$ 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 $\boxed{5}$ 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15
SITUATION	TOTAL				
		PRESENT SSF = 20 ÷ 43 X 100 = 47			

Erosion Condition Classes: *Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

(Instructions on reverse)

Form 7310-12 (1973)

Table B-10 (con.)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

By: F. S. Moore | Date: 3-75

Location: 300'W, 2400'N, SE COR. SEC. 7 T23N, R12W
MU-7011 PROFILE 44

Treatment affecting the SSF

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 $\boxed{11}$	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed $\boxed{12}$ 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 $\boxed{12}$	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills 1/2" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills 1/2" to 6" deep occur in exposed area at intervals of 5 to 10' 10 $\boxed{11}$ 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15
SITUATION	TOTAL				
		PRESENT SSF = 46 ÷	57 × 100 = 81		

Erosion Condition Classes: *Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

(Instructions on reverse)

Form 7310-12
(May 1973)

Table B-10 (con.)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

By	Date
F. G MOORE	8-75
Location 400'E, 400'N, SWCOR. SEC. 6 T23N, R12W MU-7006 PROFILE 22	
Treatment affecting the SSF	

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions $\boxed{12}$ 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
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RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 $\boxed{12}$	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		PRESENT SSF = 49 ÷	57 X 100 = 86		

Erosion Condition Classes: *Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

(Instructions on reverse)

Form 7310-12
(May 1973)

Table B-10 (con.)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

By	Date
RGMOORE	8-75
Location 2500'E, 75'N, SW COR., SEC. 6 T23N, R12W	
MU-7010 PROFILE 25	
Treatment affecting the SSF	

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 $\boxed{10}$ 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
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RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 $\boxed{12}$	May be present at 3" to 6" deep at intervals less than 5' 13 14
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SITUATION	TOTAL				
		PRESENT SSF = 46 ÷ 57 X 100 = 81			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Form 7310-12
(May 1973)

Table B-10 (con.)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

By	Date
R G MOORE	8-75
Location MU-7010 1900'E, 1800'S, NW COR. SEC. 7 T23N, R12W PROFILE 38	
Treatment affecting the SSF	

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. $\boxed{9}$ 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles $\boxed{7}$ 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
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RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills 1/2" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills 1/2" to 6" deep occur in exposed area at intervals of 5 to 10' 10 $\boxed{11}$ 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		PRESENT SSF = 46 ÷	71 X 100 = 65		

Erosion Condition Classes: *Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100*

(Instructions on reverse)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Table B-11

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
N M	FARM	--	---------- / --------	7010	R. G. MOORE	8 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	SAN JUAN	Sec. 7, T. 23N, R. 12W	277-5	----	-------	Alluvium

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
FRUITLAND	Stone -- Rock --	Alkaline Saline Water table NONE	VALLEY

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
< 3 ☒ Single ☐ Complex	SW	5885	Type WIND & WATER SSF 61 critical Class 4	-

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
5-8 TOTAL - 1st, 2nd, 3rd, 4th	53 Air 55 Soil	146 Days ---> 28°	somewhat poorly drained	Fair	Fair	-- in	--.- in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST: MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-12	10YR 6/3 D	—	C	MOD. f. SBK	HD - V. FIR V. sti. & PLS.		ff		7.9	CS
C1	12-24	10YR 6/2 D	—	CL	MASS	HD - FIR. sl. sti. & PLS.				7.8	CS
C2	24-48	10YR 6/3 D	—	SIL	MASS	soft - FRI. sli. sti. & PIS.				8.0	AS
C3	48-84	10YR 6/3	—	LS	SG	loose - nonsti & pls.				7.9	
II C4	84-120	10YR 6/3 D	—	fS	SG	loose nonsti & pls				8.1	

MASTER SITE FOR MAPPING UNIT 7010 TURLEY SERIES PROFILE 35

1925'E, 850'N, SW COR. SEC. 7, T23N, R12W

(Instructions inside back cover)

Form 7310–9a (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Table B-11 (con.)

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
NM	FARM.	--	----------/-------	7003	R G MOORE	8 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	SAN JUAN	Sec. 6, T. 23N, R. 12W	279-5	----	-------	ALLUVIUM

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
FRUITLAND	Stone -- Rock --	Alkaline Saline Water table NONE	MESA

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
0-3 ☒ Single ☐ Complex	SW	6055	Type WIND SSF 54 Class 3 MODERATE	-

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
5-8 TOTAL - 1st, 2nd, 3rd, 4th	53 Air 55 Soil	Days 146 > 28°	WELL DRAINED	GOOD	GOOD	-- in	--.- in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A & B	0-12	10YR 6/3	—	LS	f Gr	loose NON sti & pls		f & M		8.5	CS
C1ca	12-34	10YR 6/4	—	SL	MASS	sl. hard NON sti & pls.		f & M		8.7	CS
C2ca	34-48	10YR 6/3	—	SL	MASS	sl. hard sl. sti-NON pls				9.1	GS
C3	48-90	10YR 6/4	—	LS	f Gr	sl. hard NON. sti & pls.				8.5	AS
C4	90-108	10YR 6/3	—	S	SG	loose NON. sti & pls				9.2	

MASTER SITE FOR MAPPING UNIT 7003 SHIPROCK SERIES PROFILE 7

2700'E, 1225'S, NW COR. SEC. 6, T23N, R12W

(Instructions inside back cover)

Form 7310-9a (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Table B-11 (con.)

VEGETATION–SOIL DESCRIPTION

1. State NM	2. District --	3. Planning Unit --	4. Vegetation–Soil Unit /	5. Soil Map Symbol 7004	6. Surname R G MOORE	7. Date 8 mo 75 yr
8. Area --	9. County San Juan	10. Location Sec. 17, T. 23N, R. 12W	11. Photo No. 306-1	12. Writeup No. ----	13. File No. ------	14. Parent Rock Eolian & ALLUVIUM
15. Formation Name PICTURED CLIFFS	16. Surface Conditions (percent) Stone -- Rock --	17. Land Conditions Alkaline Saline Water table NONE				18. Landform SIDE SLOPE ON SANDY RIDGE
19. Slope (percent) 0-5 ☒ Single ☐ Complex	20. Aspect N	21. Elevation 5940	22. Present Erosion Type WIND SSF 47 Class 3 MODERATE			23. Hydrologic Group -
24. Precipitation (in) 5-8 TOTAL - 1st, 2nd, 3rd, 4th	25. Temperature 53 Air 55 Soil	26. Frost-free Days 146 > 28°	27. Drainage Class MOD. WELL DRAINED	28. Infiltration FAIR	29. Percolation FAIR	30. ERD -- in; 31. AWC --.- in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-6	10YR 5/3	—	LFS	F. Gr.	loose NON.sti. & Pls		few Med		8.9	CS
B21t	6-28	10YR 6/2	—	CL	med. SABK	HARD Mod.sti. & Pls	thin conti	few fine		8.1	CS
B22t	28-38	5YR 6/3	—	CL	coarse & Med. SABK	HARD Sli.sti. & Pls	thin patchy			8.5	GW
C1	38-48	5YR 6/3	—	SL	fine Gr	sli. hard NON sti. & Pls				9.3	CA
C2	48-64	10YR 6/2	—	CL	med ABK	MOD. HARD Mod.sti. & Pls.				9.0	CA
C3	64-80	10YR 6/3	—	LS	SG	sli. HARD NON.sti. & Pls				9.0	CA
C4	80-120	10YR 6/4	—	L	fine Gr.	loose NON.sti. & Pls.				8.8	

MASTER SITE FOR MAPPING UNIT 7004 DOAK SERIES PROFILE 58

350'N, 250'W, SE COR., SEC. 17, T23N, R12W

(Instructions inside back cover)

Form 7310–9a (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Table B-11 (con.)

VEGETATION–SOIL DESCRIPTION

1. State NM	2. District --	3. Planning Unit --	4. Vegetation–Soil Unit ---/---	5. Soil Map Symbol 7007	6. Surname R G MOORE	7. Date 8 mo 75 yr
8. Area --	9. County San Juan	10. Location Sec. 8, T. 23N, R. 12W	11. Photo No. 308-1	12. Writeup No. ----	13. File No. ----	14. Parent Rock Alluvium & Eolian
15. Formation Name FRUITLAND	16. Surface Conditions (*percent*) Stone -- Rock --	17. Land Conditions Alkaline Saline Water table NONE				18. Landform MESA
19. Slope (*percent*) 0-15 ☐ Single ☒ Complex	20. Aspect SE	21. Elevation 5960	22. Present Erosion MODERATE Type WIND SSF 57 Class 3			23. Hydrologic Group –
24. Precipitation (*in*) 5-8 TOTAL – 1st, 2nd, 3rd, 4th	25. Temperature 53 Air 55 Soil	26. Frost-free Days 146 > 28°	27. Drainage Class EXCESSIVELY DRAINED	28. Infiltration RAPID	29. Percolation RAPID	30. ERD -- in; 31. AWC --.- in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-3	10YR 5/3		LFS	SG	loose NON.sti & pls		Few FINE			AS
B2t	3-12	7.5YR 5/4		FSL	WEAK BK	sl. hard NON.sti & pls		Few MED.			AS
C1	12-24	10YR 6/4		LFS	SG	loose NON.sti & pls		Few FINE & MED.			CS
C2	24-38	10YR 6/4		FS	SG	loose NON.sti & pls		Few FINE			CS
C3	38-60	10YR 6/4		LS	SG	loose NON.sti & pls					

MASTER SITE FOR MAPPING UNIT 7007 MAYQUEEN SERIES PROFILE 70
1550'W, 1850'S, NE COR., SEC. 8, T23N, R12W

(*Instructions inside back cover*)

Form 7310-9a (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Table B-11 (con.)

VEGETATION–SOIL DESCRIPTION

1. State: NM
2. District: FARM
3. Planning Unit: --
4. Vegetation–Soil Unit: ---------- / --------
5. Soil Map Symbol: 7008
6. Surname: RG MOORE
7. Date: 8 mo 75 yr
8. Area: --
9. County: SAN JUAN
10. Location: Sec. 7, T. 23N, R. 12W
11. Photo No.: 277-5
12. Writeup No.: ----
13. File No.: ------
14. Parent Rock: EOLIAN SANDY MATERIAL OVER LOCAL ALLUVIUM
15. Formation Name: FRUITLAND
16. Surface Conditions (*percent*): Stone -- Rock --
17. Land Conditions: Alkaline Saline Water table NONE
18. Landform: SANDY RIDGE IN VALLEY
19. Slope (*percent*): 0-3 ☒ Single ☐ Complex
20. Aspect: SW
21. Elevation: 5910
22. Present Erosion: MODERATE Type WIND SSF 47 Class 3
23. Hydrologic Group: -
24. Precipitation (*in*): 5-8 TOTAL - 1st, 2nd, 3rd, 4th
25. Temperature: 53 Air 55 Soil
26. Frost-free: Days 146 > 28°
27. Drainage Class: SOMEWHAT EXCESSIVELY DRAINED
28. Infiltration: GOOD
29. Percolation: GOOD
30. ERD: -- in
31. AWC: --.- in

32. HORIZON	33. THICKNESS	34. COLOR (DRY / MOIST) MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
AC	0-12	10YR 6/4	—	fS	SG	loose NON-sti & pls		VF MED MS		7.9	CS
C1	12-48	10YR 6/4	—	fS	SG	sl. COMP. NON-sti & pls		few S 12-30		9.4	CS
C2	48-84	10YR 6/4	—	fS	SG	loose NON-sti & pls				9.4	CS
C3	84-108	10YR 6/3	—	LfS	SG	sl. COMP. NON-sti & pls				9.5	AB
II C4	108-120	10YR 5/2	—	SC	f ABK	MOD. HARD V. sti — sli. pls.				8.1	

MASTER SITE FOR MAPPING UNIT 7008 SHEPPARD SERIES PROFILE 23

800'E, 125'S, NW COR. SEC. 7, T23N, R12W

(*Instructions inside back cover*)

Form 7310–9a (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Table B-11 (con.)

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
NM	--	--	/	7011	R G MOORE	8 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	San Juan	Sec. 7, T. 23N, R. 12W	294-3	----	------	ALLUVIUM

15. Formation Name	16. Surface Conditions (*percent*)	17. Land Conditions	18. Landform
FRUITLAND	Stone -- Rock --	Alkaline Saline Water table NONE	VALLEY

19. Slope (*percent*)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
0-3 [X] Single [ ] Complex	SW	5920	SEVERE Type WIND & WATER SSF 81 Class 5	–

24. Precipitation (*in*)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
5-8 TOTAL – 1st, 2nd, 3rd, 4th	53 Air 55 Soil	Days 146 > 28°	POORLY DRAINED	POOR	POOR	-- in	--.- in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST: MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A & B	0-12	10YR 6/3	—	SIC	f Gr.	Sli. Hard Mod. Sti. & Pls				8.2	AS
B2tsa	12-44	10YR 6/3	—	CL	f Gr.	Soft Mod. Sti. & Pls				9.1	A
C1	44-72	10YR 6/3	—	VFS	SG	loose Non. Sti. & Pls				9.1	A
C2	72-94	10YR 6/4	—	S	SG	loose Non. Sti. & Pls				9.5	A
C3	94-108	10YR 6/3	—	LS	SG	Sl. Comp. Non. Sti. & Pls				8.3	CS
C4	108-120	10YR 6/3	—	S	SG	loose Non. Sti. & Pls.					

MASTER SITE FOR MAPPING UNIT 7011 UFFENS SERIES PROFILE 44

300'W, 2400'N, SE COR., SEC. 7, T23N, R12W

(Instructions inside back cover)

Form 7310–9a (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Table B-11 (con.)

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
NM	--	--	------/------	7006	R. G. MOORE	8 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	San Juan	Sec. 6, T. 23N, R. 12W	277-5	----	------	LOCAL ALLUVIUM OVER RESIDUAL

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
FRUITLAND	Stone -- Rock --	Alkaline Saline Water table NONE	UPLAND VALLEY SLOPES

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
0-3 ☒ Single ☐ Complex	SW	5915	SEVERE Type WATER & WIND SSF 86 Class 5	-

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
5-8 TOTAL - 1st , 2nd , 3rd , 4th	53 Air 55 Soil	Days 146 > 28°	VERY POORLY DRAINED	VERY POOR	VERY POOR	-- in	--.- in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A & B	0-12	10YR 5/2	—	C	f SABK	V. HARD V. sti & pls.				7.8	AS
Cr1	12-36	10YR 2/1	—	sh	f SABK	v. Hard v. sti & pls				6.4	
Cr2	24-36	5Y 3/2	—	sh	f SABK	v. hard. v. sti. & pls.				7.6	

MASTER SITE FOR MAPPING UNIT 7006 HUERFANO SERIES PROFILE 22

400'E, 400'N, SW COR., SEC. 6, T23N, R12W

(Instructions inside back cover)

Form 7310–9a (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Table B-11 (con.)

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
NM	--	--	---------- / --------	7010	R G MOORE	8 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	SAN JUAN	Sec. 6, T. 23N, R. 12W	277-5	----	------	ALLUVIUM

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
FRUITLAND	Stone -- Rock --	Alkaline Saline Water table NONE	VALLEY

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
0-3 [X] Single [ ] Complex	SW	5900	SEVERE Type WIND & WATER SSF 81 Class 5	-

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
5-8 TOTAL - 1st , 2nd , 3rd , 4th	53 Air 55 Soil	Days 146 > 28°	poorly drained	Fair	Fair	-- in	--.- in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-12	10YR 6/4	—	LFS	SG	SOFT, V. fri NON-sti & pls				8.5	CS
C1	12-24	10YR 6/4	—	LS	SG	Soft, loose NON. sti & pls				8.8	GS
C2	24-66	10YR 6/4	—	FS	SG	Soft, loose NON. sti. & pls.				9.5	DS
C3	66-90	7.5YR 6/4	—	FS	SG	SOFT. LOOSE NON. sti. & pls.				9.4	AS
II C4	90-120	7.5YR 4/2	—	SiC	STRONG FINE ABK	HARD, FIRM sti. & pls.				8.3	

MASTER SITE FOR MAPPING UNIT 7010 STUMBLE SERIES PROFILE 25

2500'E, 75'N, SW COR., SEC. 6, T23N, R12W

(Instructions inside back cover)

Form 7310–9a (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Table B-11 (con.)

VEGETATION–SOIL DESCRIPTION

1. State NM	2. District FARM	3. Planning Unit --	4. Vegetation–Soil Unit /	5. Soil Map Symbol 7010	6. Surname R G MOORE	7. Date 8 mo 75 yr
8. Area --	9. County SANJUAN	10. Location Sec. 7, T. 23N, R. 12W	11. Photo No. 277-5	12. Writeup No. ----	13. File No. ------	14. Parent Rock ALLUVIUM

15. Formation Name FRUITLAND	16. Surface Conditions (*percent*) Stone -- Rock --	17. Land Conditions Alkaline Saline Water table NONE	18. Landform VALLEY
19. Slope (*percent*) 0-3 ☒ Single ☐ Complex	20. Aspect SW / 21. Elevation 5885	22. Present Erosion CRITICAL Type WATER & WIND SSF 65 Class 4	23. Hydrologic Group -

24. Precipitation (*in*) 5-8 TOTAL - 1st , 2nd , 3rd , 4th	25. Temperature 53 Air 55 Soil	26. Frost-free Days 146 > 28°	27. Drainage Class POORLY DRAINED	28. Infiltration POOR	29. Percolation POOR	30. ERD -- in	31. AWC --.-- in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (*pH*)	42. BOUNDARY
A & B	0-12	10YR 5/3	—	CL	FGR to weak MED. SABK	MOD. HARD MOD. sti - sl. pls.				8.3	CS
B3	12-24	2.5Y 5/2	—	C	FGR	MOD. FRI V. sti & pls				7.8	GS
C1	24-48	2.5Y 4/2	—	C	MASS	EXT. HARD V. sti & pls.				8.5	GS
C2	48-68	2.5Y 4/2	—	C	MASS	EXT. HARD V. sti. & pls				7.8	GS
II C2	68-120	10YR 5/3	—	LFS	SG	V. FRI NON. sti & pls				9.3	

MASTER SITE FOR MAPPING UNIT 7010 LATON SERIES PROFILE 38

1900'E, 1800'S, NW COR., SEC. 7, T23N, R12W

(*Instructions inside back cover*)

Form 7310–9a (December 1970)

APPENDIX C

MOISTURE RELATIONSHIPS IN SOILS ASSOCIATED WITH VEGETATION TYPES

Contents

Tables

Figures

Methods and Concepts Used to Define Moisture Relationships in Soils Associated with Vegetation Types

Soils associated with different plant communities were sampled to define characteristics that influence infiltration, storage, and depletion of water under the existing climate conditions. This was done to establish evidence of what the soils and related vegetation resources are prior to disruption if the area is surface mined for coal.

An understanding of soil-water-plant relationships prior to disturbance will yield information that will be useful when the areas are rehabilitated following mining.

Water enters soils associated with a cover of native vegetation through a well-established system of voids because these soils have been undisturbed for thousands of years. These voids are primarily the result of previous wettings. Water separates and expands the distance between soil particles or aggregates of soil particles, creating voids. As moisture is depleted from soils, there is a partial collapse of voids, but the amount of remaining void is proportionate to the degree to which soils were wetted. The stability of voids is influenced by plant roots, humus derived from them and other factors that influence soil structure and aggregate stability.

This well-established system of voids will be disrupted if the soil is stripped off the surface, stockpiled, and subsequently repositioned. If individual horizons from the same soil are redeposited at the same slope and with the same exposure, after a period of time a similar pattern of voids should become established. Evidence that previous proportions of voids originally measured have been reestablished could be one measure of the success of rehabilitation efforts.

The proportion of voids present with depth in soils can be determined from the weight per unit volume of soil. This is accomplished by determining the weight of all the soil obtained with an auger from consecutive decimeter increments of depth. The soil at the base of the auger does not consistently break off at the same position. To compensate for this source of variation, volume weight values for a given depth are computed as the average of three depths including depths above and below the increment being measured. The quantitiy of water required to fill the voids to capacity is then computed, assuming that soil particles have a specific gravity of 2.65 g/cm^3. The resultant value is defined by the term "Void-Moisture Capacity or VMC." Void-moisture capacity can be determined from volume weight, either graphically or by computation, using the relationship illustrated in figure C1. When void-moisture capacity is plotted on the horizontal axis against depth on the vertical axis (figs 14-24 in main text), the relationship between void-moisture capacity (VMC) and the degree to which the various horizons in the soil profile have been wetted becomes evident. Void-moisture capacities are greatest near the surface, characteristically diminishing with depth in the soil profile.

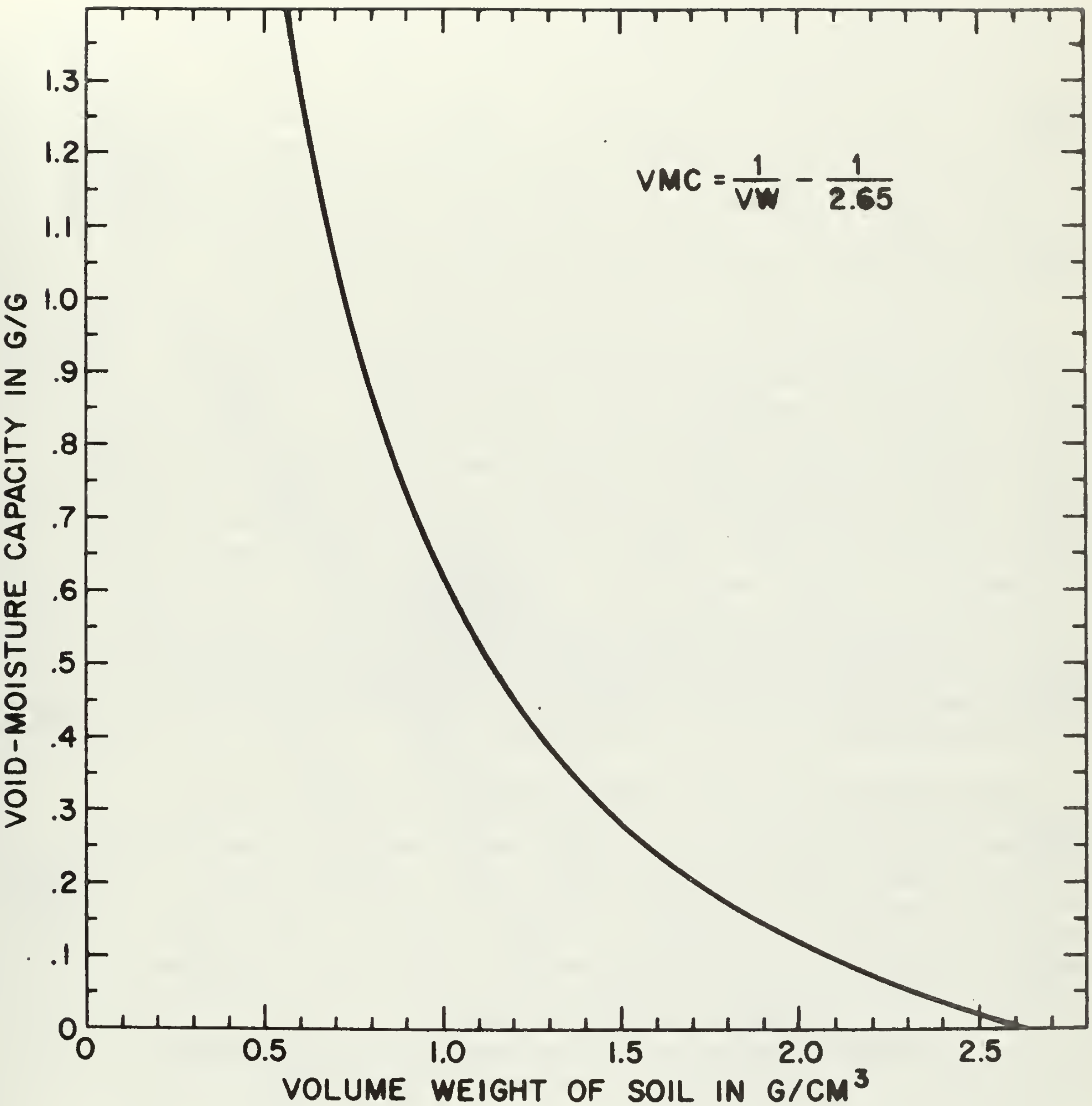

Figure C1.--Relationship between volume weight (VW) and void-moisture capacity (VMC) of soil.

Water entering the soil through voids flows down over the surfaces of soil particles, where a portion of it is retained by forces of attraction. Water in the forefront becomes adsorbed to particle surfaces, while water subsequently penetrating the soil flows down over water already adsorbed and adheres to surfaces encountered at greater depths. Under wet conditions, this process can continue until water migrates down to the water table. Most of the adsorptive surface on which water is stored is provided either by humus or by minute plate-like particles of clay. Larger spherical particles of silt or sand function primarily as occupiers of space. They, in effect, dilute the amount of adsorptive surface provided by clay and humus (Miller and McQueen, 1972).

Computations of water storage and subsequent depletion from soils require a definition of relationships between moisture-retention capabilities of soils and variations in the force with which moisture is retained as the thickness of adsorbed films of moisture vary. Three separate moisture-content and retention-force relationships must be considered: first, capillary water; second, adsorbed water; and third, structured water. These relationships are presented diagrammatically in figure C2 to facilitate their comprehension. The diagram is based on the findings of McQueen and Miller (1974). Water is retained with the least force at or immediately above a water table. The retention force increases proportionately to height of rise by capillarity above the water table. Since a cubic centimeter (cm^3) of water weighs 1 gram (g), the retention force 1 cm above the water table is 1 g/cm^2 and at 10 cm it is 10 gm/cm^2. The maximum height that water actually rises by capillarity can be shown to be approximately 220 cm. (See Meinzer, 1923 or McQueen and Miller, 1972.)

Water retained in contact angles between soil particles by capillary forces occurs on top of multimolecular films of water already adsorbed to particle surfaces. Quantities of water retained in the capillary range, therefore, are a function of both the amount of adsorptive surface and geometry of the pores. The term, "adsorbed," applies to water attracted to surfaces by forces resembling gravity. These forces are the result of molecular attractive forces (Low, 1961). The occurrence of adsorbed water beneath capillary water is illustrated in the diagram (fig. C2). Capillary water exists permanently only in the capillary fringe above a water table. Capillary water is probably present as soils are wetted from the surface, but soon drains away leaving only films of adsorbed water. We have obtained evidence of the presence of water retained as films at retention forces less than 220 g/cm^2 rather soon after snowmelt or rainfall. At higher levels of retention force, only adsorbed water has been found to be present (Miller and McQueen, 1972).

Quantities of water adsorbed to soils with a force of 220 g/cm^2 are used to define relative differences in moisture-retention capability. This is illustrated (by relationships for two soils) in figure C2, which shows that different moisture-retention capabilities affect adsorbed water proportionately while capillary water does not vary proportionately.

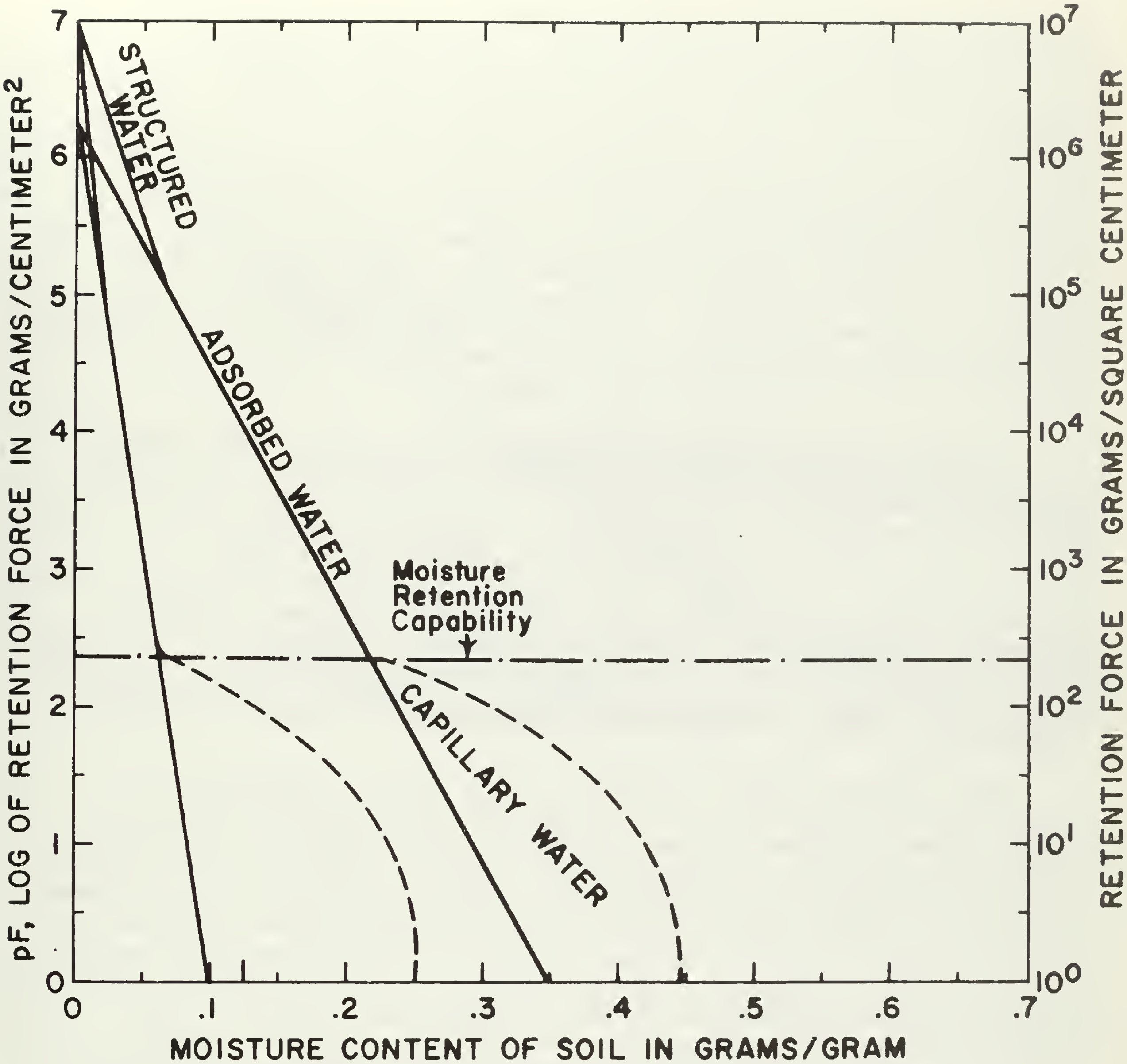

Figure C2.--Diagram illustrating relationships between units used to define retention force and ranges of retention force over which structured water, adsorbed water, and capillary water occur in soils, and the effect of differences in moisture-retention capabilities on quantities of water retained.

For example, in figure C2 moisture contents at pF 2.34 or moisture-retention capabilities of the two soils are .06 and .215 gm/gm. At pF 2.34 the soil with the greatest moisture-retention capability retains 3.58 times as much water as the soil with the lowest moisture-retention capability. At pF 4.00 or any level of stress between pF 2.34 and 5.00, the one soil will retain 3.58 times as much water as the other soil. Comparisons of the relative capability of soils to retain adsorbed water could actually be made at any level of stress over which adsorbed water is prevalent, because the proportions of water adsorbed to each soil are constant at any given level of sorption force. The term, "moisture-retention capability, or MRC" is somewhat synonymous with the term, "field capacity," but, as utilized, is much more specific because it is based on adsorptive surface available in each soil and is independent of overlying or underlying strata and time of drainage.

Retention force increases exponentially as the thickness of adsorbed films of water decreases. From the diagram in figure C2 it is evident that equal increments of adsorbed water are depleted from surfaces in each of the soils as the retention force increases from 1 to 10, 10 to 100, 100 to 1,000, 1,000 to 10,000, 10,000 to 100,000 or 100,000 to 1,000,000 gm/cm^2. The use of larger numbers associated with higher levels of retention force is inconvenient, particularly in graphs. Instead, exponential notations can be used as illustrated in figure C2. Schofield (1935) proposed the use of logarithms rather than exponents. He proposed that the term, "pF," be used to designate retention force expressed as logarithms as is also illustrated in figure C2.

Only adsorbed water is present over the range of retention force from 220 g/cm^2 to 100,000 g/cm^2 (pF 2.34 to 5.00). This facilitates construction of graphs that can be used to approximate the relationship between moisture-content and retention-force for soils from saturation to dryness, as illustrated in figure C2. All that is required is a measure of moisture content and the related retention force within the range from pF 2.34 to 5.00. The most precise method of obtaining the relationship between moisture-content and retention-force is the "Wide-Range Gravimetric Method for Measuring Moisture Stress," of McQueen and Miller (1968). Moisture stress is determined from the moisture content of standard filter papers at moisture equilibrium with soil samples using the relationship illustrated in figure C3. The moisture content of the soil is determined gravimetrically.

The moisture-retention capabilities of soils can be approximated from saturation-moisture capacities if relationships between these two variables have been established for the soils of an area. Such relationships are shown for Bisti West area soils in figure 27A in the main report. Moisture-retention capabilities estimated from saturation-moisture capacity are not as accurate as values determined from moisture-content and moisture-stress values but could be used for practical purposes if time or laboratory facilities are not available.

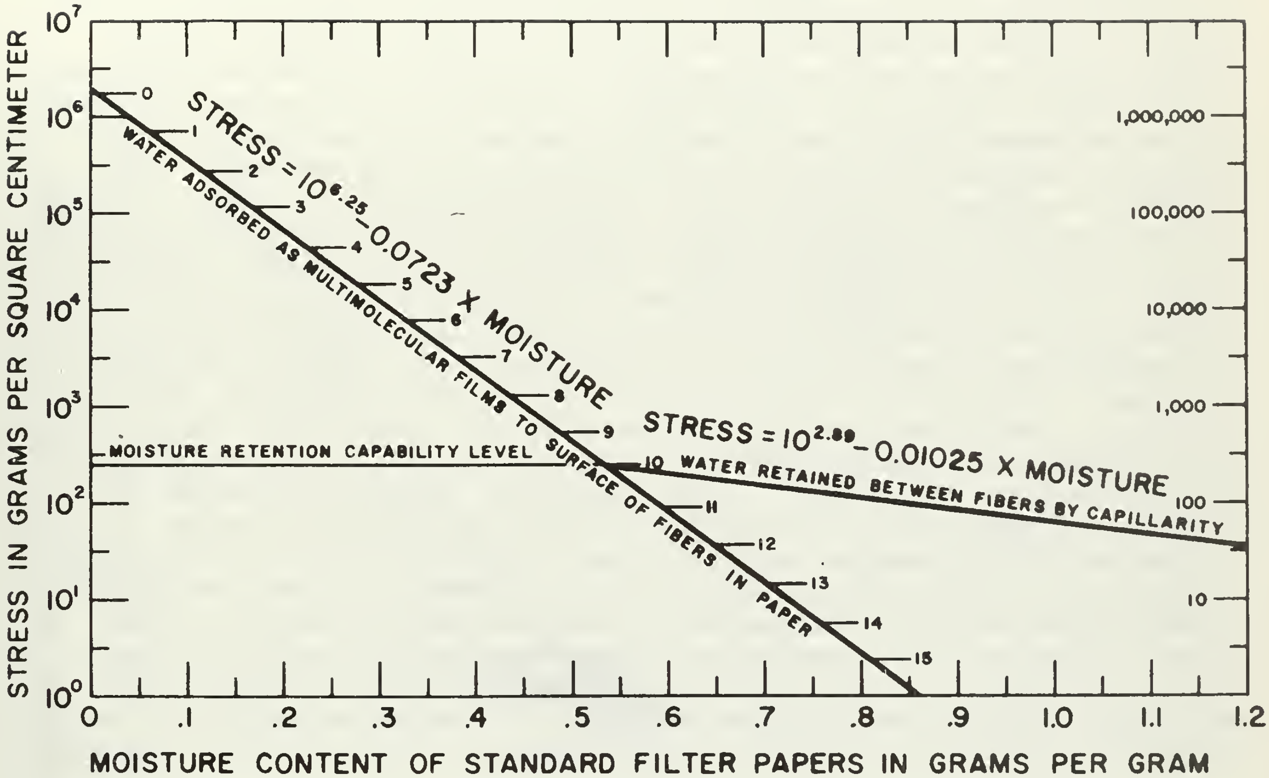

Figure C3.--Relationship between moisture content and moisture stress (moisture-retention force) of filter papers used to measure the moisture stress of field soil samples.

Moisture contents at 15 atmospheres stress (pF 4.2), as characteristically measured by the Soil Conservation Service, could also be used for defining the relationship between moisture content and retention force. A straight line is extended down from pF 6.25 through a point representing moisture content of the soil at any measured pF value between 2.34 and 5.00. This line represents variations in quantities of adsorbed moisture from pF 6.25 to pF 0. It is essential to be able to evaluate relationships between moisture-content and retention-force above the so-called wilting point (15 atmospheres) because values exceeding 15 atmospheres are consistently achieved in association with native vegetation. A line is then extended up from the moisture content at pF 5.00 to pF 7.00 on the vertical axis. This line represents water held between the lattices of expanding clays as well as to external surfaces. (On this line, there is a $10^{0.39}$ increase in the exponential value for moisture stress for each additional molecular layer of water desorbed from the surface of the soil particles.) This water, because of its proximity to the surfaces of charged clay particles, can assume a structure resembling ice (Low, 1961). Very little of this water is available for use by vegetation, but it can be depleted from the soil by evaporation. Since this water is lost, it must be replenished before water can become available for beneficial use by vegetation. Relationships used to estimate moisture content in the range of retention forces where structured water predominates, are, therefore, essential for accurate computation of water storage and depletion from surface horizons. The range of moisture contents and retention forces encountered under capillary conditions is approximated if required by sketching a curved line down from the moisture content at pF 2.34 to the moisture content at saturation where the retention force is zero (fig. C2).

The moisture content at saturation can also be used to characterize soils in lieu of textural designations. The moisture content of soils at saturation is designated by the term, "Saturation-Moisture Capacity," or the symbos "SMC." SMC values are measured as prescribed by Richards and others (1954). If ovens to dry the soils are not available, saturation-moisture capacity can be approximated from the weight of a known volume of saturated soil using a relationship such as that shown in figure C4. The moisture content of soil at saturation, according to Richards and others (1954) ". . . is directly related to the field moisture range." Stiven and Khan (1966) presented results indicating that the moisture content of soil at saturation is quantitatively related to the clay content of soils. They, therefore, concluded that the moisture content of saturated samples of soil "Could be used as a means of classifying a soil quantitatively." Another advantage of using saturation-moisture capacity to characterize soil is that coarse material can be retained in the sample and its influence on moisture-retention capabilities evaluated (Shown and others, 1964). Measures of proportions of sand, silt, and clay present are characteristically used to classify soils but they are of little value for determining moisture-retention capabilities of the materials described. Standard hydrometer methods (ASTM, 1964) can yield erroneous estimates of the clay content of soils, particularly for saline soils (Rolfe, Miller, and McQueen, 1960). For the convenience of those who think of soils by textural designations, Miller and others (1969) related saturation-moisture capacity to

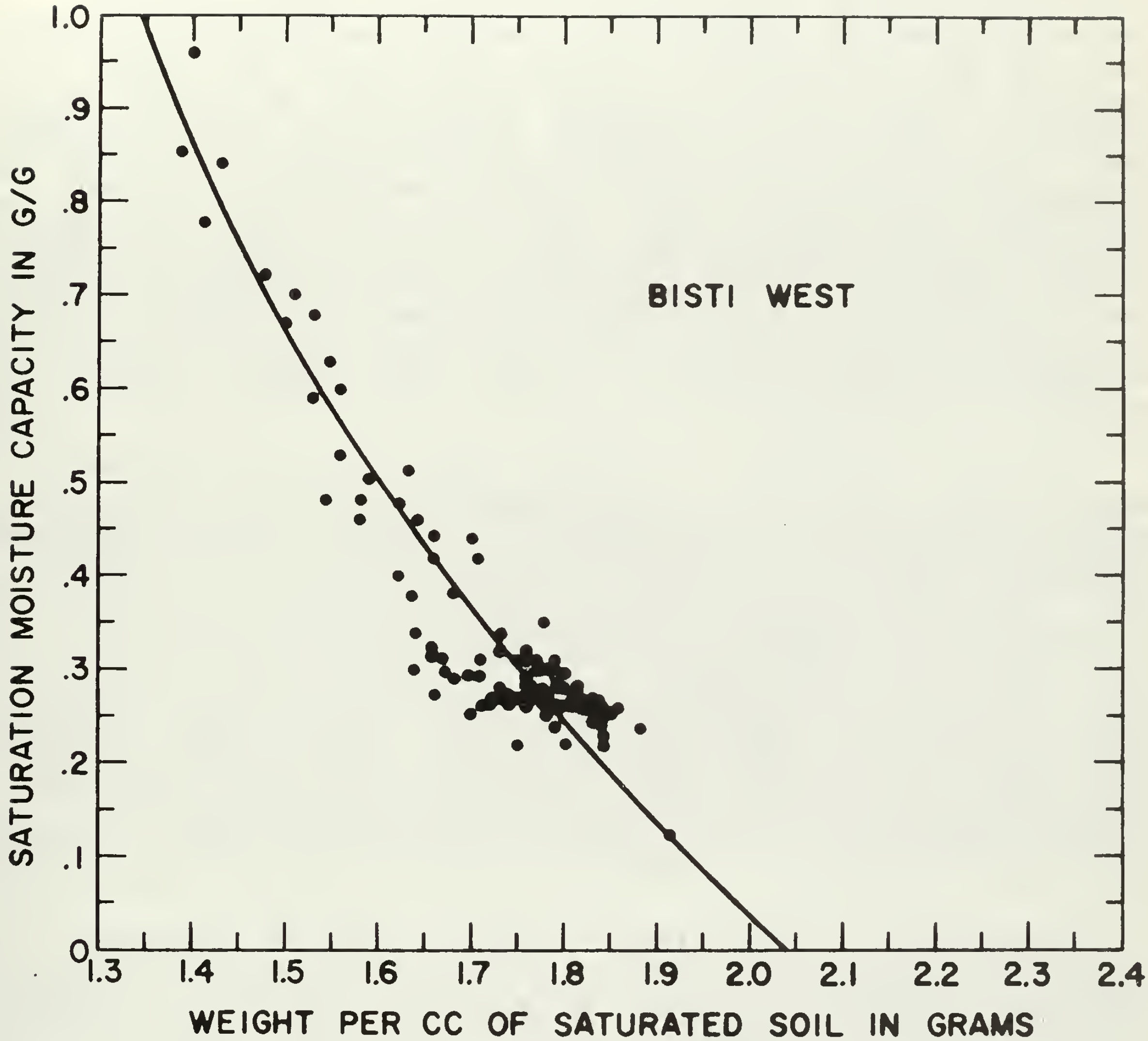

Figure C4.--Relationship between weight of a cubic centimeter of saturated soil and the water content of saturated soil from the Bisti West study area.

soil texture. They used Soil Conservation Service criteria (USDA, 1951, p. 212) for determining soil textural class in the field by feeling wet soil with the fingers. Soils having SMC values less than 0.25 were designated as very coarse and could be classified as being either gravelly fine sand, sand, fine sand, or loamy sand. Soils having SMC values between 0.25 and 0.34 were classified as being coarse. By feeling with the fingers, these soils were classified as being either sandy loam, fine sandy loam, or silty loam. Soils having saturation-moisture capacities between 0.34 and 0.43 were classified as being medium textured. These soils were either silty loam, clay loam, or silty clay loam. Soils having saturation-moisture capacities from 0.43 to 0.52 were designated as fine and were classified as either fine sandy clay loam, silty clay loam, clay loam, or silty clay. Soils with SMC values exceeding 0.52 were designated as very fine and classified as either silty clay or clay. With this information, it would be difficult to do more than designate a range of moisture-retention capabilities.

Electrical conductivity of saturated samples of soil is measured to obtain an index of salinity. In many immature desert soils, this is the primary evidence usable to define depths to which leaching and accumulation occur, particularly when there has not been sufficient time or moisture for redistribution of clay from near the surface to depth. Salts are characteristically leached out of the surface horizon to depths where field capacity is achieved. These salts accumulate in the soil beneath where soil becomes progressively less wet with depth. Thus, resulting patterns of electrical conductivity can be used to define depths to which field capacity is achieved as well as the depth of the horizon beneath where wetness decreases with depth. Electrical conductivity values tend to be uniform or vary in proportion to changes in moisture-retention capability with depth where field capacity is achieved but tend to increase with depth as the degree of wetting in the subsoil decreases.

Soil reaction or pH also tends to vary with depth in response to the pattern of wetting. The pH of soil varies with proportions of soluble and exchangeable ions in the soil. The proportion of sodium to calcium and magnesium tends to increase in the direction of moisture migration (Miller and Ratzlaff, 1965). As a result, pH values also tend to increase in the direction of moisture migration. The increase in alkalinity per unit of depth is greater in the surface horizon where field capacity is achieved than it is where wetness decreases with depth. This is apparently the result of more ion exchange occurring in the more completely and frequently wetted horizon than in less completely wetted soil beneath.

Differences in the quantities of roots present in each sampling increment also provide evidence of depths to which different degrees of wetting are consistently achieved. The greatest quantities of roots per cubic decimeter characteristically occur at or near the surface. The largest proportions of roots occur to depths where field capacity is achieved. The upper portion of this horizon contains the most roots because it is occasionally rewetted by summer rains. Roots tend to diminish progressively with depth in the lower horizon where the degree of wetting decreases with depth.

Resistance to detachability in flowing water was also measured on dried cakes of previously saturated and mechanically disturbed soil. This procedure obviously does not provide a good measure of relative erodibility of undisturbed soils as they now exist in the field, but should provide a useful measure of resistance to erosion after the soils have been stripped off the surface, stockpiled, and repositioned. Roots and decomposition products of roots tend to influence resistance to erosion more than texture or salinity. Surface samples of soil, because of their higher root and humus contents, resist decomposition of soil structure by aggregating better than subsurface samples of soil. Data derived from surface soils are, therefore, most likely to reflect the relative erodibility of soils as they now exist in the field. It is quite possible that the most erodible soil materials are also the most permeable and, therefore, are subjected to less erosion force than more resistant materials that are less permeable. It is essential, therefore, to have some index of the relative permeability of soils.

Permeability of soils is proportional to quantities of voids greater than those filled with water at field capacity (Baver, 1938). With this in mind, both moisture-retention capacity (MRC) and void-moisture capacity (VMC) values are plotted with depth in graphs for each of the soils investigated (figs. 14-24). Void-moisture capacities characteristically exceed moisture-retention capabilities to depths where field capacity is achieved. In finer textured soils where voids are a function of the degree of wetness achieved, void-moisture capacities progressively become less with depth than moisture-retention capabilities. The absence of void space inhibits deeper penetration of water when excess water is available. In coarser soils, void-moisture capacities often naturally exceed moisture-retention capabilities. In these soils, water can penetrate readily to great depths.

Depths to which soils are wetted to moisture-retention capacity, and where degrees of wetness decrease with depth, are determined from evidence provided by comparisons of void-moisture capacity and moisture-retention capability data. Comparisons of electrical conductivity and pH as well as root concentrations are also utilized. The different hydrologic horizons are defined with the greatest confidence when all available evidence is in agreement.

Soils are samples at or as near the maximum period of dryness when possible so that moisture contents and related retention forces associated with minimum levels of moisture storage can actually be measured. These soil values vary with climate regions as well as kind and amount of plant cover, while maximum levels of moisture storage and related retention forces are a function of the moisture-retention capability of the soil. Maximum levels of storage and the related retention force are, therefore, approximated, while minimum levels of storage and related retention forces are actually measured. Ideally, both extremes would be measured but time limitation did not permit obtaining maximum wetness data.

The various horizons encountered at different depths in soil profiles are numbered consecutively instead of attempting to define genetic horizons. Genetic horizons, if properly defined, should, however, be indicators of hydrologic characteristics of horizons because they are products of recurring patterns of wetting and drying. Horizon 1, as utilized, usually defines the portion of the soil that is both wetted to moisture-retention capacity or wetter and is dried beyond the transpiration limit by evaporation. Transpiration limit is the maximum moisture stress to which a given species of vegetation is physiologically capable of removing water from the soil. Horizon 2 relates to the portion of the soil that is wetted to moisture-retention capacity and dries to the transpiration limit. Horizon 3 is used to define the lower portion of the solum where the soil is wetted progressively less with depth and is dried to the transpiration limit. If contact with the water table was made, horizon 3 could represent equilibrium conditions with the water table or a larger number is used to define this horizon, if required.

Once the depth of the 1, 2, and 3 horizons is defined, lines representing recurring minimum and maximum levels of retention force are plotted with depth for each profile sampled. Then average volume weight and moisture-retention capability values are computed and tabulated for each horizon. Lines representing differences in retention force (pF) as adsorbed water varies from saturation to dryness are constructed for each horizon. A line representing structured water is plotted for the 1 horizon if pF 5.00 is exceeded. The curved line defining the capillary range is drawn if contact was made with a water table. These linear relationships are used to determine moisture contents of each horizon under wet and dry conditions (figs. 14-24 in main text). The depth of water in decimeters depleted between wet and dry conditions is computed as the product of the change in moisture content, volume weight, and depth of the horizon in decimeters. The depth of water depleted from each horizon is presented (figs. 14-24 in main text). Lines representing moisture-retention capabilities could be used as management tools when replacement of stockpiled materials is planned. The identical lines (figs. 14-24 in main text) can be used if materials from horizons as defined are stockpiled separately. New lines must be plotted if materials are mixed. These relationships will be quite useful if decreases or increases in depths of wetting are planned, or will result from management because moisture contents at any level of stress can be determined from these relationships. Use of similar relationships derived from field data will be essential if materials obtained from soil profiles are rearranged from the original order of occurrence.

TABLE C1 SOIL MOISTURE DATA FOR SPECIFIC VEGETATION-TYPE SITES

SYMBOLS: H, HORIZON; DM, DEPTH IN DECIMETERS; VW, VOLUME WEIGHT IN GRAMS PER CUBIC CENTIMETER; SM, SOIL-MOISTURE CONTENT IN GRAMS PER GRAM; PF, LOG OF MOISTURE STRESS IN GRAMS PER SQUARE CENTIMETER; MRC, MOISTURE-RETENTION CAPABILITY AT PF 2.34 IN GRAMS PER GRAM; VMC, VOID-MOISTURE CAPACITY IN GRAMS PER GRAM; SMC, SATURATION-MOISTURE CAPACITY IN GRAMS PER GRAM; VS, VOLUMETRIC SHRINK IN CUBIC CENTIMETERS PER CUBIC CENTIMETER; EC, ELECTRICAL CONDUCTIVITY OF SATURATED SOIL IN MILLIMHOS PER CENTIMETER; PH, LOG OF HYDROGEN CONTENT IN MOLS PER LITER; ROOTS, WEIGHT OF ROOTS CONTAINED PER CUBIC DECIMETER OF SOIL; DET, DETACHABILITY OF SOIL BY FLOWING WATER IN KILOGRAMS PER HOUR FROM A SQUARE METER OF SURFACE; CPR, COARSE PARTICLE RATIO - WEIGHT OF PARTICLES OF DIAMETER GREATER THAN .25 MILLIMETERS DIVIDED BY TOTAL WEIGHT OF SOIL PARTICLES; MW, MOISTURE CONTENT WHEN WET IN GRAMS PER GRAM; MD, MOISTURE CONTENT WHEN DRY IN GRAMS PER GRAM; MDM, MOISTURE STORAGE DEPLETED IN DECIMETERS.

N 8

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	0.82	.171	4.14	.319	0.84	0.84	.57	6.25	6.78	0.0	6.1	.001
1	2	0.82	.087	5.72	.646	0.84	0.68	.47	8.33	6.35	0.0	4.5	.008

N 6

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
1	1	1.08	.167	4.12	.308	0.55	0.44	.28	1.24	5.20	0.4	6.4	.021
2	2	1.15	.231	3.72	.359	0.49	0.48	.33	1.56	4.82	1.1	2.7	.018
	3	1.45	.192	4.30	.388	0.31	0.51	.39	3.25	4.20	0.6	5.2	.039
3	4	1.48	.176	4.40	.374	0.30	0.53	.45	4.81	4.06	0.7	5.0	.029
	5	1.39	.172	4.37	.360	0.34	0.50	.39	4.72	4.00	0.2	5.3	.031
	6	1.20	.265	4.45	.580	0.46	0.17	.12	3.47	3.85	0.2	328.6	.066
	7	1.20	.283	4.39	.597	0.46	0.58	.22	1.61	3.75	0.0	244.0	.074

N 3

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
1	1	1.05	.215	2.23	.210	0.58	0.46	.34	1.35	7.50	3.8	7.5	.020
	2	1.19	.220	3.88	.365	0.46	0.70	.39	3.79	7.56	5.1	13.0	.010
2	3	1.14	.168	4.37	.350	0.50	0.48	.22	4.24	7.58	1.7	52.5	.054
	4	1.06	.143	3.83	.231	0.56	0.31	.05	2.69	7.81	0.2	735.2	.088
	5	0.96	.116	3.43	.162	0.66	0.27	.06	2.48	7.73	0.3	698.1	.091
3	6	0.96	.087	3.52	.125	0.66	0.25	.10	1.88	7.72	0.1	784.3	.088

N 9

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.48	.082	2.21	.079	0.30	0.22	.12	0.34	7.70	1.7	76.8	.048
1	2	1.38	.063	3.41	.087	0.35	0.27	.14	0.49	7.85	2.6	77.5	.020
	3	1.59	.067	4.92	.197	0.25	0.59	.36	1.25	7.95	0.4	3.9	.027
2	4	1.55	.071	4.88	.203	0.27	0.42	.30	3.33	7.65	1.3	49.8	.006
	5	1.77	.110	4.94	.330	0.19	0.63	.47	4.17	7.55	0.8	23.8	.005
3	6	1.49	.121	4.98	.373	0.29	0.67	.50	3.38	7.45	0.2	1.4	.001
	7	1.49	.111	4.89	.323	0.29	0.85	.61	1.72	7.85	0.1	0.6	.000

N 4

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.25	.109	1.34	.087	0.42	0.30	.12	0.27	7.92	2.6	220.6	.046
1	2	1.39	.116	1.47	.095	0.34	0.32	.15	0.60	8.08	3.2	177.6	.048
	3	1.47	.065	4.71	.167	0.30	0.44	.26	1.70	8.22	2.2	2.0	.013
2	4	1.77	.085	4.50	.191	0.19	0.46	.37	5.00	7.70	3.3	5.5	.008
	5	1.83	.072	4.67	.180	0.17	0.44	.37	5.21	7.62	1.6	10.3	.003
3	6	1.94	.116	4.83	.323	0.14	0.72	.55	5.10	6.74	0.7	5.9	.001
	7	1.83	.125	5.36	.548	0.17	1.17	.71	2.27	7.05	0.2	9.3	.000
	8	1.83	.113	5.16	.407	0.17	1.17	.62	2.17	7.32	0.1	7.5	.000

N 5

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	0.85	.144	1.22	.112	0.80	0.31	.18	0.39	6.92	6.8	51.6	.021
1	2	1.00	.144	2.12	.137	0.62	0.40	.15	0.78	6.77	28.1	0.5	.009
	3	1.01	.109	4.43	.235	0.61	0.60	.51	1.11	7.28	3.2	1.6	.007
	4	1.27	.182	3.58	.267	0.41	0.67	.58	1.28	7.40	0.9	1.3	.007
2	5	1.51	.120	4.52	.272	0.29	0.78	.57	2.50	7.15	1.1	0.9	.002
	6	1.73	.120	4.85	.338	0.20	0.96	.54	3.13	7.18	1.4	0.5	.000
	7	1.83	.116	4.68	.290	0.17	1.06	.59	2.27	7.30	0.6	0.5	.000
3	8	1.83	.105	4.70	.267	0.17	1.01	.54	1.92	7.60	1.0	0.5	.005

TABLE C1

SOIL MOISTURE DATA FOR SPECIFIC VEGETATION-TYPE SITES (CONT'D)

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
						N10							
	1	1.08	.058	2.16	.056	0.55	0.31	.20	0.41	7.35	3.9	3.3	.015
	2	1.19	.042	2.86	.048	0.46	0.32	.15	0.28	7.60	2.8	28.2	.028
	3	1.52	.030	4.11	.055	0.28	0.31	.18	0.26	7.42	2.0	157.4	.026
1	4	1.70	.031	4.34	.064	0.21	0.29	.14	0.37	7.78	1.8	184.4	.017
	5	1.94	.040	4.49	.090	0.14	0.31	.13	0.54	7.85	3.2	180.2	.009
	6	1.89	.044	4.32	.091	0.15	0.30	.15	0.63	7.95	3.2	122.9	.010
	7	1.73	.038	4.51	.087	0.20	0.30	.15	0.83	7.95	2.4	96.1	.013
2	8	1.58	.033	4.65	.082	0.26	0.32	.17	1.04	7.75	1.6	96.8	.021
	9	1.72	.030	4.81	.081	0.21	0.28	.14	1.19	7.78	0.9	184.5	.026
	10	1.68	.031	4.84	.087	0.22	0.25	.15	1.04	7.75	0.5	131.6	.036
	11	1.64	.028	4.84	.079	0.23	0.29	.17	0.81	7.80	0.3	75.1	.024
3	12	1.56	.026	4.81	.072	0.26	0.27	.12	0.83	7.90	0.1	126.0	.031
	13	1.95	.031	4.82	.085	0.14	0.27	.15	1.00	7.80	0.2	58.6	.027
	14	1.86	.029	4.84	.081	0.16	0.27	.10	1.14	7.75	0.2	133.3	.043
	15	1.72	.027	4.76	.072	0.20	0.25	.12	0.82	7.85	0.0	231.1	.031
	16	1.72	.028	4.64	.068	0.20	0.26	.11	0.98	7.80	0.1	184.6	.029
						N 7							
	1	1.19	.038	1.75	.034	0.46	0.26	.14	0.16	7.10	1.8	243.5	.076
	2	1.24	.047	1.36	.038	0.43	0.26	.14	0.15	7.60	0.8	470.6	.072
	3	1.49	.036	2.16	.035	0.29	0.28	.16	0.16	7.65	0.5	479.2	.044
	4	1.55	.018	3.91	.031	0.27	0.25	.12	0.15	7.85	0.5	484.3	.086
	5	1.79	.021	3.84	.035	0.18	0.27	.17	0.17	7.58	0.4	487.0	.078
1	6	1.79	.023	3.45	.032	0.18	0.26	.17	0.16	7.95	0.3	511.1	.081
	7	2.00	.026	3.39	.035	0.12	0.26	.15	0.17	7.78	0.2	488.8	.075
	8	1.76	.029	2.51	.030	0.19	0.27	.16	0.18	7.85	0.3	487.6	.078
	9	1.56	.026	3.19	.034	0.26	0.26	.17	0.17	7.78	0.1	326.9	.073
	10	1.29	.031	2.87	.036	0.40	0.27	.16	0.19	7.72	0.1	244.6	.080
2	11	1.68	.031	3.08	.038	0.22	0.26	.15	0.23	7.75	0.2	323.4	.070
	12	2.12	.031	3.52	.045	0.10	0.24	.15	0.34	7.72	0.3	510.6	.074
	13	2.56	.032	3.14	.040	0.01	0.25	.16	0.35	7.85	0.4	511.3	.072
3	14	2.17	.037	2.29	.037	0.08	0.25	.16	0.39	7.47	0.3	515.1	.070
	15	1.90	.041	2.14	.039	0.15	0.26	.13	0.48	7.65	0.3	321.0	.076
	16	1.90	.041	2.19	.039	0.15	0.26	.15	0.52	7.79	0.3	493.6	.069
						N 1							
	1	1.20	.057	3.29	.076	0.45	0.29	.19	0.33	6.72	14.1	31.3	.032
1	2	1.28	.067	2.27	.067	0.40	0.28	.17	0.30	6.78	4.2	121.4	.039
	3	1.67	.041	4.44	.089	0.22	0.28	.17	0.28	6.87	2.4	98.5	.033
	4	1.83	.054	4.44	.117	0.17	0.31	.21	0.33	6.93	4.5	109.2	.029
	5	2.09	.053	4.42	.114	0.10	0.30	.20	0.33	7.00	4.1	65.4	.021
	6	1.76	.048	4.34	.098	0.19	0.30	.19	0.34	7.07	3.0	54.7	.024
	7	1.65	.053	4.30	.107	0.23	0.28	.19	0.32	7.27	0.8	30.3	.015
	8	1.41	.051	4.07	.092	0.33	0.28	.20	0.31	7.36	0.8	49.1	.022
	9	1.56	.051	3.91	.085	0.26	0.26	.17	0.31	7.51	0.5	67.0	.016
2	10	1.63	.049	3.60	.072	0.24	0.27	.17	0.35	7.69	0.5	118.5	.022
	11	1.85	.045	3.64	.067	0.16	0.27	.14	0.45	7.42	1.0	184.3	.029
	12	1.71	.056	4.13	.103	0.21	0.32	.17	1.16	7.46	1.5	77.1	.014
	13	1.64	.056	4.40	.118	0.23	0.35	.26	1.47	7.47	0.4	40.6	.006
3	14	1.82	.051	4.44	.110	0.17	0.31	.22	1.72	7.49	0.3	49.8	.016
	15	1.81	.039	4.49	.088	0.17	0.26	.15	1.43	7.55	0.6	171.1	.032
	16	1.81	.024	4.46	.054	0.17	0.26	.14	0.78	7.23	0.4	135.5	.051

TABLE C1

SOIL MOISTURE DATA FOR SPECIFIC VEGETATION-TYPE SITES (CONT'D)

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
						N 2							
	1	1.38	.043	3.97	.074	0.35	0.26	.19	0.36	7.54	3.4	50.4	.029
	2	1.37	.058	3.86	.095	0.35	0.30	.22	0.36	7.61	2.2	59.3	.027
1	3	1.50	.060	4.37	.125	0.29	0.32	.23	0.38	7.68	1.8	32.6	.020
	4	1.79	.052	4.53	.120	0.18	0.31	.23	0.35	7.85	1.5	55.6	.019
	5	1.83	.041	4.47	.091	0.17	0.28	.18	0.30	7.95	0.7	123.7	.020
	6	1.88	.039	4.47	.087	0.16	0.28	.17	0.27	8.16	0.4	122.0	.014
	7	1.64	.048	4.38	.101	0.23	0.27	.17	0.33	8.39	0.7	25.4	.010
	8	1.74	.043	4.33	.088	0.20	0.24	.17	0.30	8.38	0.3	34.3	.028
2	9	1.87	.039	4.25	.076	0.16	0.22	.13	0.31	8.37	0.3	195.6	.035
	10	1.85	.052	4.34	.106	0.16	0.29	.16	0.58	8.42	0.3	160.0	.042
	11	2.05	.045	4.73	.116	0.11	0.27	.19	0.78	8.28	0.2	143.8	.042
3	12	2.05	.037	4.24	.073	0.11	0.23	.16	0.86	8.21	0.1	93.9	.059
						N11							
	1	1.09	.083	3.37	.113	0.54	0.29	.29	0.53	7.55	2.8	44.6	.001
	2	1.19	.034	5.25	.134	0.46	0.31	.14	0.45	7.55	2.6	37.3	.005
	3	1.38	.033	5.21	.125	0.35	0.30	.14	0.46	7.85	0.9	99.7	.003
1	4	1.50	.032	4.92	.095	0.29	0.27	.13	0.52	7.55	5.0	114.8	.007
	5	1.75	.049	4.77	.131	0.19	0.32	.17	0.83	7.65	1.9	35.7	.001
	6	1.71	.051	4.78	.138	0.21	0.29	.20	1.09	7.70	2.3	45.3	.010
2	7	1.84	.057	4.82	.156	0.17	0.34	.25	1.16	7.65	2.6	28.1	.006
	8	1.69	.089	4.86	.254	0.21	0.49	.39	4.17	7.45	3.2	32.8	.005
	9	1.90	.091	4.75	.237	0.15	0.48	.40	3.57	7.30	1.2	16.6	.004
3	10	1.71	.073	4.87	.208	0.21	0.42	.33	3.13	7.40	1.6	15.4	.005
	11	1.54	.055	4.76	.146	0.27	0.34	.25	1.47	7.55	1.2	23.8	.008
	12	1.61	.066	4.71	.168	0.24	0.38	.24	1.22	7.72	0.6	15.0	.005
	13	1.67	.052	4.71	.133	0.22	0.30	.18	1.19	7.70	0.9	18.0	.035
	14	1.79	.033	4.57	.078	0.18	0.26	.15	0.63	7.80	0.3	225.9	.053
	15	1.50	.037	4.56	.085	0.29	0.27	.14	0.68	7.95	0.2	127.4	.046
	16	1.81	.040	4.59	.096	0.17	0.29	.15	0.77	7.80	0.4	73.4	.041
	17	1.79	.031	4.53	.071	0.18	0.26	.16	1.67	7.45	0.3	120.0	.059
	18	1.83	.028	4.27	.056	0.17	0.28	.17	1.67	7.55	0.1	305.5	.055
	19	1.57	.025	4.14	.046	0.26	0.27	.13	0.83	7.95	0.1	91.1	.067
	20	1.93	.032	4.14	.060	0.14	0.27	.15	1.19	7.80	0.3	92.4	.063
	21	1.99	.042	3.75	.066	0.12	0.28	.13	0.93	8.20	0.1	9.2	.064
	22	2.03	.048	2.48	.049	0.12	0.27	.10	0.71	8.15	0.0	75.5	.088
	23	1.74	.087	2.03	.081	0.20	0.31	.16	1.04	8.05	0.1	15.3	.080
	24	1.71	.104	1.17	.080	0.21	0.27	.13	0.86	8.10	0.1	50.9	.078
	25	1.76	.119	0.26	.078	0.19	0.26	.15	0.66	8.12	0.0	189.8	.079
	26	1.73	.130	1.28	.103	0.20	0.24	.13	0.72	8.15	0.3	120.0	.077
	27	1.65	.141	1.34	.113	0.23	0.22	.11	0.61	8.20	0.3	162.3	.073
	28	1.65	.140	1.94	.128	0.23	0.24	.10	0.69	8.15	0.6	155.8	.067

APPENDIX D

GEOLOGY

Contents

Page

Tables

No.

Table D-1

SELECTED LABORATORY ANALYSES OF CORE SAMPLES

EMRIA

Bisti West Site

(see Table B-6 for complete results)

Drill Hole	Depth (ft)	Hydraulic Cond (in/h)	Settling Vol (ML)	ECX10^3 @ 25C	Na (Me/L)	ESP (%)	CEC
DH-1	15 - 44	0	60	1.63	17.7	8.2	100
"	44 - 63	0	70	1.81	15.6	0.5	74.0
"	63 - 77	0	27	2.81	25.6	11.8	68.0
"	77 -128	0	60	2.08	19.0	27.5	55.2
"	128 -160	0	60	1.63	13.7	22.1	75.2
"	176 -193	0	32	1.92	17.0	45.8	24.0
"	203 -212	0	63	2.73	25.5	25.8	68.0
"	232 -242	0	62	6.51	60.0	18.0	68.0
"	253 -282	0	70	2.26	19.0	15.9	82.0
"	287.6-296	0	46	1.84	16.0	18.3	54.0
"	338 -346	0	82	1.59	13.6	22.4	75.2
"	357 -370	0	26	2.56	21.0	27.8	3.9
DH-2	17.2- 33.7	0	250	6.39	56.4	13.5	106
"	33.7- 38.4	0	75	8.77	82.0	15.3	108
"	39.6- 47.7	0	80	2.88	25.2	20.2	94.0
"	48.9- 58.6	0	105	1.65	14.0	20.1	74.0
"	58.6- 78.5	0	100	1.10	8.8	25.8	23.2
"	82.0- 96.5	0	220	0.94	7.4	19.2	70.0
"	102 -132	0	125	3.43	32.6	16.3	92.0
"	132 -157	0	100	1.73	16.7	19.6	82.0
DH-3	12 - 32	0	37	7.25	56.0	7.2	74.0
"	32 - 52	0	100	3.60	32.4	25.7	88.0
"	57 - 79	0	90	2.19	18.0	21.7	86.0
"	79 -106	0	75	2.15	19.0	29.9	80.0
DH-4	28 - 69	0	200	5.08	45.6	21.4	92.0
"	71 -104.8	0	230	1.04	7.6	48.4	18.0
DH-5	22 - 37	0	230	11.1	112	23.1	100.0
"	37 - 57	0	205	3.64	32	26.8	102.0
"	64 - 74.8	0	200	1.72	15.8	28.2	88.0
"	81 -101.5(1)	0	65	1.92	16.0	50.2	15.6
"	81 -101.5(2)	0	110	1.29	15.2	25.3	72.0
DH-6	33 - 50	0	150	2.30	22.0	19.6	78.0
"	31 - 56	0	95	1.48	13.8	59.7	12.8
"	56 - 76	0	110	2.82	28.0	27.1	90.0
"	76 - 86	0	150	1.17	11.5	28.7	78.0
"	104 -133	0	200	0.92	9.5	50.2	28.0
DH-7	13 - 24	0	270	4.30	43.0	9.0	66.0
"	24 - 36	0	100	6.10	66.0	18.2	98.0
"	36 - 47	0	160	1.65	17.5	23.6	92.0
"	47 - 69	0	57	1.50	16.0	43.4	24.0
"	69 - 78	0	100	2.54	27.0	18.2	106
"	94 -104	0	165	1.52	16.0	29.5	76.0
"	104 -136	0	105	1.25	12.0	51.2	15.6
"	138 -174	0	110	1.82	20.0	24.4	104
"	185 -195	0	100	2.15	22.0	20.7	20.7

GEOLOGIC LOG OF DRILL HOLE

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO DH-1 LOCATION T23N, R12W, Section 6 NE¼SE¼NW¼ GROUND ELEV 6040± DIP (ANGLE FROM HORIZ.) 90°

COORDS. N ... E ...

BEGUN 7-11-75 FINISHED 7-28-75 DEPTH OF OVERBURDEN ... TOTAL DEPTH 400 ft. BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with 4 3/4" drag bit 0.0 to 14.8 with air.	4-3/4 RB								0.0			0.0 to 14.8 Sand, fine to medium, silty, loose, brown. SM
Cored 14.8' to 81.6' with double tube core barrel and NX metal bit using air.	NX H	21, 100							14.8			14.8 to 44.0 Shale, clayey, silty, firm, easily cut with fingernail, closely fractured, grey, brown with brown stained fractures; slakes rapidly.
Lost 80% of air between 29.0' and 34.0'.		71, 0										
Changed to water at 81.6'. Cored with water and drill mud 81.6' to 400'.		75, 66										
		100, 100, 100							44			44.0 to 62.8 Siltstone, fine sandy, slightly clayey, firm, easily broken with fingers, brown and grey; slakes slightly. Hard concretion at 60.0'.
Core in fragments to 6" lengths 14.8' to 81.6', in 2" to 36" lengths 81.6' to 400'. Core broken during drilling and in boxing.		63, 100, 30							62.8			62.8 to 77.6 Sandstone, fine grained, silty, weakly cemented, easily crushed with pliers, laminated to massive, light grey.
U.S.B.R. Personnel and Drill rig. Failing 1500		62, 100							77.6			77.6 to 116.4 Shale, clayey, firm, easily cut with fingernails, fissile, dark grey; slakes rapidly and softens on wetting, gypsum zone 115.0 to 116.4.

EXPLANATION

Type of hole D = Diamond H = Hoystellite S = Shot C = Churn
Hole sealed
Approx. size of hole (X series)
Approx. size of core (X series)
Outside dia. of casing (X series)
Inside dia. of casing (X series)

CORE RECOVERY

GEOLOGIC LOG OF DRILL HOLE

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO DH-1 LOCATION T23N, R12W, Sec. 6, NE¼, SE¼, NW¼ GROUND ELEV 6040± DIP (ANGLE FROM HORIZ.) 90°

COORDS. N E.

BEGUN 7-11-75 FINISHED 7-28-75 DEPTH OF OVERBURDEN TOTAL DEPTH 400 ft. BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	NX H	100										Shale (continued)
Cored with water obtained from City of Farmington 81.7' to 222.0'		100							116.4			116.4 to 128.4 Shale, clayey, silty, firm, can be cut with fingernail with difficulty, fissile, grey.
		100, 100							128.4			128.4 to 168.0 Shale, clayey, fine sandy 140.5 to 142.7 and 160.6 to 165.0', firm, can be cut with fingernail, fissile, grey; softens on wetting.
Cored with water obtained from El Paso Natural Gas Co., White Rock Station 222.0' to 400.0'.		100										
		100										
Pulled casing and plugged hole 7-28-75		100										
		100							168.0			168.0' to 193.8' Sandstone, fine grained, silty with siltstone 168.4 to 170.0, slightly clayey, clay shale 182.0 to 183.0 and 193.0 to 193.8, firm, can be scratched with fingernail, laminated 168.0 to 175.5, massive 175.5 to 193.0, light grey.
		100, 100, 100										
									193.8			Coal.
		100							194.5			194.5 to 203.0 Siltstone, clayey, firm, massive, grey.

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole: D = Diamond, H = Hoystell to, S = Shot, C = Churn

Hole sealed: P = P[illegible], C = Cemented, Cs = Bottom of casing

Approx. size of hole (X series): Ex = 1 1/2", Ax = [illegible], Bx = [illegible], Nx = 3"

Approx. size of core (X series): Ex = [illegible], Ax = [illegible], Bx = 1 5/8", Nx = 2 1/8"

Outside diameter of casing (X series): Ex = 1 13/16", Ax = 2 1/4", Bx = 2 7/8", Nx = 3 1/2"

Inside diameter of casing: Ex = 1 1/2", Ax = 1-29/32", Bx = 2 3/8", Nx = 3"

Table D-2 (con.)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO. DH-1 LOCATION T23N, R12W, Sec. 6 NE¼, SE¼, NW¼ COORDS N E GROUND ELEV 6040± DIP (ANGLE FROM HORIZ.) 90°

BEGUN 7-11-75 FINISHED 7-28-75 DEPTH OF OVERBURDEN TOTAL DEPTH 400 ft. BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	NX D											Siltstone (continued)
		100							203			203.0 to 212.0 Shale, clayey, silty, firm, easily cut with fingernail, fissile, grey; softens on wetting.
		80							212			212.0' to 222.0 Siltstone, clayey, firm, faintly laminated, grey. Limy at 222.0
		100							222			222.0 to 235.0 Shale, clayey, silty 228.5 to 232.5, firm, can be cut with fingernail, fissile, grey; softens on wetting.
									235			235 to 236.3' Coal.
		100							236.3			236.3 to 238.7 Shale, clayey, firm, fissile, black.
									238.7			238.8 to 241.7' Coal.
									241.7			241.7 to 246.0 Siltstone, clayey, firm, massive, grey.
		100							246			246.0 to 253.0 Shale, clayey, silty, firm, fractured with slickensides, fissile, grey.
		100							253.0			253.0' to 282 Shale, clayey, carbonaceous, soft to firm, fissile, black; softens on wetting.
		100										
		100										
		100							282			282.0 to 287.6 Shale, clayey, gypsum seams (1/8") 283.0 to 283.5, firm to soft, massive, light grey; softens on wetting. (Bentonite)
		100							287.6			287.6 to 297.5 Shale, clayey, silty 287.6 to 295.0, firm, grey to black; softens on wetting.
									297.5			297.5 to 317.5 Coal.

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series)
Approx. size of core (X series)
Outside dia. of casing (X series)
Inside dia. of casing (X series)

Table D-2 (con.)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO DH-1 LOCATION T23N,R12W,Sec.6 NE¼,SE¼,NW¼ GROUND ELEV 6040± DIP (ANGLE FROM HORIZ.) 90°

COORDS. N E.

BEGUN 7-11-75 FINISHED 7-28-75 DEPTH OF OVERBURDEN TOTAL DEPTH 400 ft. BEARING

DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, C, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	NX H											Coal (continued)
	310	100							310			
									317.5			317.5 to 320.0 Shale, clayey, firm to moderately hard, fissile, grey.
	320	100							320			320.0 to 338.5 Coal.
	330	100							330			
	340	100							338.5 / 340			338.5 to 346.2 Shale, clayey, firm, fissile, black.
									346.2			346.2 to 353.2 Coal.
	350	100							350			
									353.2			353.2 to 357.5 Shale, clayey 353.2 to 354.2, silty, firm, grey.
									357.5			357.5 to 359.5 Coal.
	360	100							360			359.5 to 400 Sandstone, fine grained, silty, slightly clayey, firm, can be crushed with fingers, weakly cemented, friable, massive, light grey to grey.
	370	100							370			
	380	100							380			
	390	100							390			
	400	100							400			

Interpretive Notes:

0-14.8': Dune Sand
14.8'-193.8': Kirtland Formation
193.8'-359.5': Fruitland Formation
359.5'-400': Pictured Cliffs Formation

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole: D = Diamond, H = Hawstellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cs = Cemented, Cb = Bottom of casing

Table D-2 (con.)

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Bisti- West PROJECT B.L.M. STATE New Mexico

HOLE NO DH-2 LOCATION T23N, R12W, Sec.6SE¼, SE¼, SW¼ GROUND ELEV 5920± DIP (ANGLE FROM HORIZ.) 90°

COORDS N E

BEGUN 8-29-75 FINISHED 8-30-75 DEPTH OF OVERBURDEN TOTAL DEPTH 197.0 ft BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED * Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with 4 3/4" rock bit with air 0.0' to 12.5'.	4-3/4 RB								0.0			0.0 to 7.0 Sand, fine to medium grained, silty, uncemented, brown. (Logged from cuttings.)
Set 4" casing to 12.5'.									7.0			7.0 to 12.5 Shale and sandstone, soft and weathered. No recovery. Logged from drill report.
Cored with NX metal bit and double tube core barrel with water and drill mud, 12.5' to 197.0'.	NX H								12.5			12.5 to 17.2 Siltstone, clayey, many carbonized plant remains, firm, grey; softens on wetting.
		74							17.2			17.2 to 38.4 Shale, clayey, some carbon, firm, can be cut with fingernail, few slickensides, many brown stained partings, dark grey, light grey 23.7 to 26.0 ; softens on wetting and slakes rapidly on drying.
		100										
Core of shale and coal in 12" to 24" lengths, siltstone and sandstone 24" to 72" lengths. Broken in boxing.		100							38.4			38.4 to 39.6 Coal.
									39.6			39.6 to 47.7 Shale, clayey, firm, easily cut with fingernail, massive, brown stained partings 39.6 to 41.0, dark grey; softens on wetting, slakes rapidly.
		100							47.7			47.7 to 48.9 Coal.
									48.9			48.9 to 58.6 Shale, clayey, and sandstone 52.5-53.5, firm, dark grey; softens on wetting, slakes rapidly.
		100							58.6			58.6 to 78.5 Sandstone, fine grained, silty, clayey, limy, firm, can be cut with fingernail, hard calcite zone 67.0 to 68.5 , massive to laminated, light grey.
Coal crumbles when picked up for sacking.		100										
* Use of drill mud prevented measuring water table. Plugged hole 8-30-75		100							78.5			78.5 to 82.0 Shale, clayey, silty, firm, dark grey; slakes on drying.
Drilled by U.S.B.R. personnel and Gov't. drill. Failing 1500									82.0			82.0 to 96.5 Sandstone, fine grained, silty, limy, firm, can be scratched with fingernail, laminated, light grey.
		100										
		100							96.5			96.5 to 102.0 Coal.

EXPLANATION

CORE LOSS

CORE RECOVERY

RB = Rock Bit

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn

Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

Approx. size of hole [illegible]: Ex = 1-1/2", Ax = [illegible], Bx = [illegible], Nx = 3"

Approx. size of core [illegible]: Ex = 7/8", Ax = [illegible], Bx = [illegible], Nx = [illegible]

Outside dia. of casing [illegible]: Ex = 1-13/16", Ax = [illegible], Bx = [illegible], Nx = [illegible]

Inside dia. of casing [illegible]: Ex = 1-1/2", Ax = [illegible], Bx = [illegible], Nx = [illegible]

Bisti - West

GEOLOGIC LOG OF DRILL HOLE

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO. DH-2 LOCATION T23N, R12W, Sec. 6, SE¼, SE¼, SW¼ GROUND ELEV 5920± DIP (ANGLE FROM HORIZ.) 90°

COORDS. N E

BEGUN 8-29-75 FINISHED 8-30-75 DEPTH OF OVERBURDEN TOTAL DEPTH 197.0 ft. BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
												Coal (continued)
	110	100							102			102.0 to 113.0 Shale, clayey, firm, crumbles on drying, dark grey.
									113			113.0 to 119.6 Coal.
	120	100							119.6			119.6 to 132.3 Shale, clayey, silty 122.0 to 124.0, firm, can be cut with fingernail, few slickensided partings, dark grey; softens on wetting, crumbles on drying.
	130	100										132.3 to 137.0 Coal.
									137.0			137.0 to 138.0 Shale, clayey, dark grey.
	140	63										138.0 to 143.1 Coal.
									143.1			143.1 to 151.0 Shale, clayey, firm, fissile, few slickensided partings, dark grey; softens on wetting.
	150	100										151.0 to 156.0 Coal.
		100							156			156.0 to 160.5 Siltstone, clayey, firm, laminated, grey.
	160								160.5			160.5 to 164.0 Coal.
		100										164.0 to 166.5 Shale, clayey, firm, dark grey.
	170	100										166.5 to 197. Sandstone, fine grained, silty, clayey, firm, easily crushed with fingers, massive, light grey.
	180	100										
	190											
	197	100							197			

Interpretive Notes

0-7': Alluvium
7.0'-166.5': Fruitland Formation
166.5'-197': Pictured Cliffs Formation

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn

Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

Table D-2 (con.)

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Bisti--West PROJECT B.L.M. STATE New Mexico

HOLE NO. DH-3 LOCATION T23N, R12W, Sec. 7, SE¼, SE¼, NW¼ GROUND ELEV. 5900± DIP (ANGLE FROM HORIZ.) 90°

COORDS. N. E.

BEGUN 7-31-75 FINISHED 8-5-75 DEPTH OF OVERBURDEN TOTAL DEPTH 353.0 ft. BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 82.1 feet from ground 8-5-75 LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with 4 3/4" rock bit 0.0' to 12.0'. Set 4" casing to 12.0'.	4-3/4 RB								0.0–32			0.0 to 32.0 Clay, silty, much carbon 30.0 to 32.0 , firm, 0.0 to 30.0 , soft and light 30.0 to 32.0 , brown, black 30.0 to 32.0 .
Cored with NX metal bit and double tube core barrel with water and drill mud, 12.0' to 149.5'.	NX H	40										
		30										
Core of shale and coal in 12" to 24" lengths, siltstone and sandstone in 24" to 72" lengths. Broken in boxing.		70							32–52.8			32.0 to 52.8 ' Shale, clayey, silty, firm, easily cut with fingernail, massive, many brown stained partings 32.0 to 49.0 , brown 32.0 to 41.0 , grey 41.0 to 53.4 ,' softens on wetting, slakes on drying.
		100							52.8–53.4			52.8 to 53.4 Sandstone, moderately hard.
									53.4–57.7			53.4 to 57.7 Coal.
Coal crumbles when picked up for sacking.		57							57.7–81.8			57.7 to 81.8 Shale, clayey, silty firm, easily cut with fingernail, massive grey 53.4 to 79.5 , black 79.5 to 81.8 , and Sand, fine grained, silty, uncemented, brown, 72.3 to 77.5 . (Sand appears to be cavings, but driller reported sand was encountered after .2 of shale was cored.)
		100										
		40							81.8–89.5			81.8 to 89.5 Coal.
		100										
Drilled by U.S.B.R. personnel with Gov. drill. Failing 1500		100							89.5–100			89.5 to 100.0 Shale, clayey, silty, firm, can be cut with fingernail, fissile, few slickensided partings, dark grey; softens on wetting, slakes on drying.

EXPLANATION

CORE LOSS

CORE RECOVERY

RB = Rock Bit

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn

Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

Approx. size of hole: [illegible]

Approx. size of core: [illegible]

Outside dia. of casing: [illegible]

Inside dia. of casing: [illegible]

GEOLOGIC LOG OF DRILL HOLE

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO. DH-3 LOCATION T23N, R12W, Sec. 7, SW¼, SE¼, NW¼ COORDS N. E. GROUND ELEV 5900± DIP (ANGLE FROM HORIZ.) 90°

BEGUN 7-31-75 FINISHED 8-5-75 DEPTH OF OVERBURDEN TOTAL DEPTH 353.0 ft. BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 82.1' from ground 8-5-75 LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
												100.0 to 105.5 Coal.
		100							105.5			105.5 to 112.7 Siltstone, clayey, fine sandy, firm, grey.
									112.7			112.7 to 116.9 Coal.
		100							116.9			116.9 to 150.0 Sandstone, fine grained, silty, shaly, 116.9 to 118.5, little lime, firm to moderately hard, weak to moderately cemented, grey.
		100										
		100										
		100										
Changed to 4 3/4" rock bit; reamed hole to 150.5' Drilled without coring 150' to 353.0'. Electric logs made in the hole by U.S.G.S.									149.5			149.5 to 353.0 [redacted]stone with few small seams of coal, hardness increases with depth. Log based on drillers report from 149.5 to 353.0.
Lost about 50% estimated 15 gallons/minute, of drill water near 310.0'.												Interpretive Notes 0-32': Alluvium & Decomposed to Intensely Weathered Formation Rock 32'-116.9': Fruitland Formation 116.9'-353': Pictured Cliffs Formation
2" Diameter plastic pipe perforated below 150' was installed 8-5-75												

Depth scale: 110, 120, 130, 140, 150, 160, 170, 180, 190

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole: D = Diamond, H = Hystellite, S = Shot, C = Churn

Hole scale: P = Packer, Cm = Cemented, Cs = Bottom of casing

GEOLOGIC LOG OF DRILL HOLE

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO. DH-4 LOCATION T23N, R12W, Sec. 7, SW¼, SE¼, SW¼ GROUND ELEV. 5880± DIP (ANGLE FROM HORIZ.) 90°

COORDS. N E

BEGUN 8-6-75 FINISHED 8-7-75 DEPTH OF OVERBURDEN TOTAL DEPTH 104.8 ft. BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with 4 3/4" rock bit and air 0.0' to 15.0'. Set 4" casing to 15.0'.	4-3/4 RB								0.0–15			0.0 to 15.0 Clay, silty, fine sandy, firm, brown. (Cuttings)
	NX H	60							15–24.6			15.0 to 24.6 Shale, clayey, silty, soft, easily crumbled, grey, brown.
Cored with NX metal bit and double tube core barrel with water and drill mud 15.0' to 104.8'.		100							24.6–27.7			24.6 to 27.7 Coal.
		100							27.7–40.3			27.7 to 40.3 Shale, clayey, silty 27.7 to 30.3, carbonaceous, limy 39.3 to 40.3, firm, easily cut with fingernail, black, softens on wetting, slakes on drying.
Core of shale and coal in 6" to 24" lengths; sandstone in 24" to 72" lenghts. Broken in boxing.		80							40.3–50.3			40.3 to 50.3 Coal.
		10							50.3–58.1			50.3 to 58.1 Shale, clayey, firm, fissile, dark grey.
		100							58.1–64.9			58.1 to 64.9 Coal.
Coal crumbled when picked up for sacking.									64.9–69.2			64.9 to 69.2 Shale, clayey, sandstone 65.2 to 66.2, firm, dark grey.
									69.2–71.4			69.2 to 71.4 Coal.
Plugged hole and pulled casing 8-7-75. Drilled by U.S.B.R. personnel and Gov't drill. Failing 1500.		100, 100, 100, 100							71.4–104.8			71.4 to 104.8 Sandstone, fine grained, silty, moderately hard, weakly cemented, can be crushed with fingers, massive, grey.

EXPLANATION

CORE LOSS

CORE RECOVERY

RB= Rock Bit

Type of hole D = Diamond, H = Haystellite, S = Shot, C = Churn

Hole sealed P = Packer, Cr = Cemented, Cs = Bottom of casing

Approx. size of hole (X series) Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = [illegible]

Approx. size of core (X series) Ex = 7/8", Ax = 1 1/8", Bx = 1 5/8", Nx = 2 1/8"

Outside diam. of casing (X-series) Ex = 1 13/16", Ax = 2 1/4", Bx = [illegible], Nx = 3 1/2"

[illegible] (X-series) Ex = 1 1/2", Ax = 1 29/32", Bx = [illegible]

Table D-2 (con.)

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO DH-4 LOCATION T23N, R12W, Sec. 7, SW¼, SE¼, SW¼ COORDS N. E. GROUND ELEV 5980± DIP (ANGLE FROM HORIZ.) 90°

BEGUN 8-6-75 FINISHED 8-7-75 DEPTH OF OVERBURDEN TOTAL DEPTH 104.8 ft. BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FEET) FROM (P, Cs, or Cm)	TD	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
									104.8			Sandstone (continued)

Interpretive Notes

0-15': Alluvium & Decomposed to Intensely Weathered Formation Rock

15'-71.4': Fruitland Formation

71.4'-104.8': Pictured Cliffs Formation

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . . D = Diamond, H = Heystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . Ex = 1-1/2" Ax = 1-7/8" Bx = 2-3/8" Nx = 3"
Approx. size of core (X-series) . Ex = 7/8" Ax = 1-1/8" Bx = 1-5/8" Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = [illegible] Ax = 2-1/4" Bx = 2-7/8" Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = [illegible] Ax = 1-29/32" Bx = [illegible]

Bisti - West

Table D-2 (con.)

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE Bisti - West PROJECT BIM STATE New Mexico

HOLE NO. DH 5 LOCATION T23N, R12W, Sec. 17, NE¼, NE¼, NW¼ GROUND ELEV. 5925± DIP (ANGLE FROM HORIZ.) 90°

COORDS. N ... E ...

BEGUN 8-19-75 FINISHED 8-21-75 DEPTH OF OVERBURDEN ... TOTAL DEPTH 300 ft. BEARING ...

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not Measured LOGGED BY K. Cooper LOG REVIEWED BY ...

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Ce, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Used 4 3/4" rock bit with air 0.0' to 20.0'.	4 3/4" RB											
Set 4" Casing to 20.0'									10			0.0 to 20.0 Sand, fine, silty, firm, uncemented, tan. SM
Cored with NX, metal bit and double tube core barrel 20.0' to 101.5'.	NX H	70							20, 22			20.0 to 22.0 Sandstone, fine, soft, grey
		100							30			
Core in 2' to 10' lengths. Broken in boxing.		70										
		100							40, 50			22.0 to 57.1 Shale, clayey, carbonaceous 24.0 to 26.0, 34.5 to 35.5, 49.0 to 49.5, firm, crumbly, earthy, weathered and brown 20.0 to 37.5; fissile, dark grey to black 37.5 to 57.1.
Coal fell apart when picked up for sacking.		100							57.1, 60			57.1 to 64.0 Coal.
		100							64, 70			64.0 to 74.8 Shale, clayey, fine sandy 64.5 to 65, 66.6 to 67.0, 74 to 74.8, firm, fissile, dark grey.
Shale and siltstone softens on wetting and slakes on drying.		100							74.8			74.8 to 81.0 Coal.
Drilling mud prevented logging cuttings 101.5' to 300.0'.		100							80, 81			81.0 to 86.5 Shale, siltstone, and sandstone, soft, dark grey.
									86.5, 90			86.5 to 93.0 Sandstone, fine grained, silty, firm, grey.
U.S.B.R. personnel and drill rig, Failing 1500.		100							93, 101.5			93.0 to 101.5 Shale, clayey, silty, little carbon, firm, laminated, grey; softens on wetting.

Interpretive Notes

0-20': Dune Sand & Alluvium

20'-81': Fruitland Formation

Fruitland Formation - Pictured Cliffs Formation contact at 81'

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole

Hole sealed

RB = Rock Bit

D = Diamond, H = Hardmetal, S = Shot, C = Churn

Reamed 4 3/4" from 20.0 to 101.5.
Drilled without coring 101.5' to 300'.
Hole was electrially logged by U.S.G.S.
Two inch diameter pipe perforated below 100 feet installed 8-22-75.

Table D-2 (con.)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Bisti - West PROJECT B L M STATE New Mexico

HOLE NO DH 6 LOCATION T23N, R12W, Sec. 8, NE¼, NE¼, SW¼ GROUND ELEV 5950± DIP (ANGLE FROM HORIZ.) 90°

COORDS. N. E.

BEGUN 3-15-75 FINISHED 8-16-75 DEPTH OF OVERBURDEN TOTAL DEPTH 148.9 ft. BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Used 4 3/4" rock bit with air 0.0 to 7.0'	4 3/4 RB											0.0 to 13.0 Shale, clayey, crumbly, weathered, brown and grey. (Logged from cuttings)
Set 4" casing to 7.0'	NX H	100							13.0			13.0 to 16.3 Sandstone, fine grained silty, soft, grey.
Cored with NX metal bit and double tube core barrel 7.0' to 148.9'		100										16.3 to 20.6 Coal.
									20.6			20.6 to 24.1 Shale, clayey, much carbon, soft, black.
		100							24.1			24.1 to 26.2 Coal.
									26.2			26.2 to 33.0 Siltstone, clayey, little carbon, firm, grey.
		100							33.0			33.0 to 34.6 Shale, clayey, soft.
Core in 1' to 10' lengths. Broken in boxing.									34.6			34.6 to 40.5 Coal.
		100							40.5			40.5 to 51.0 Shale, clayey, silty, easily cut with fingernail, massive, dark grey; softens on wetting, slakes on drying.
		100							51.0			51.0 to 56.0 Sandstone, fine grained, silty, little carbon, weakly cemented with hard zones, laminated, grey.
Coal fell apart on sacking.									56.0			56.0 to 66.9 Shale, clayey, much carbon, firm, dark grey; softens on wetting, slakes on drying.
		100							66.9			66.9 to 68.0 Coal.
Shale softens on wetting and slakes on drying.		100										68.0 to 76.0 Shale, clayey, silty, firm, dark grey to grey; softens on wetting, slakes on drying.
Pulled casing and plugged hole 8-16-75		100							76.0			76.0 to 87.8 Siltstone, clayey, easily cut with fingernail, massive, grey.
									87.8			87.8 to 88.6 Coal.
USBR personnel and drill rig. Failing 1500.		100							88.6			88.6 to 93.3 Shale, clayey, firm, dark grey.
									93.3			93.3 to 99.1 Coal.
									99.1			

EXPLANATION

CORE LOSS

CORE RECOVERY

RB = Rock bit

Type of hole	D = Diamond, H = Hay teller, S = Shot, C = Churn
Hole sealed	P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series)	Ex = 1-1/2", Ax = [illegible] 8", Bx = 2-3/8", Nx = [illegible]
Approx. size of core (X-series)	Ex = 7/8", Ax = [illegible] 3", Bx = 1-[illegible] 8", Nx = 2-[illegible]
Outside dia. of casing (X-series)	Ex = 1-13/16", [illegible] Bx = 2-7/8", Nx [illegible]
Inside dia. of casing (X-series)	Ex = 1-1/2", [illegible] Bx = [illegible] 3", Nx [illegible]

Table D-2 (con.)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO DH 6 LOCATION T23N, R12W, Sec. 8, NE¼, NE¼, SW¼ GROUND ELEV 5950± DIP (ANGLE FROM HORIZ.) 90°

COORDS N. E.

BEGUN 8-15-75 FINISHED 8-16-75 DEPTH OF OVERBURDEN TOTAL DEPTH 148.9 ft. BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	NX H	100										99.1 to 104.5 Siltstone, clayey, firm, laminated, grey.
		100							104.5			104.5 to 133.8 Sandstone, fine grained, silty, limy, weakly cemented, easily crushed with pliers, laminated to massive, grey; hard concretion 128.4 to 128.8.
		100							133.8			133.8 to 138.4 Coal.
		100							138.4			138.4 to 141.9 Shale, clayey, sandy. 138.5 to 139.8, firm, dark grey.
		100							141.9			141.9 to 142.8 Coal.
									142.8			142.8 to 146.0 Shale, clayey, firm, dark grey.
									146.3			146.3 to 147.5 Coal.
									147.5			147.5 to 148.9 Shale, clayey, firm, dark grey.

Depth scale: 110, 120, 130, 140, 50, 60, 70, 80, 90

<u>Interpretive Notes</u>

0-148.9': Fruitland Formation

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn

Hole sealed: P = Packer, Cm = Cemented, Cs = bottom of casing

Approx. size of hole [illegible] Ex = [illegible] Ax = [illegible] 7/8", Bx = 2 3/8", Nx = 3"

Approx. size of core [illegible] Ex = 7/8" Ax = 1 1/8", Bx = 1 5/8", Nx = 2-1/8"

Outside dia. of casing [illegible] Ax = 2 1/4", Bx = 2 7/8", Nx = 3-1/2"

Inside dia. of casing [illegible] Ax = 1 29/32", Bx = 2 3/8, Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO DH 7 LOCATION T23N, R12W, Sec. 8, NE¼, NE¼, NW¼ GROUND ELEV 5945± DIP (ANGLE FROM HORIZ.) 90°

COORDS. N. E.

BEGUN 8-8-75 FINISHED 8-12-75 DEPTH OF OVERBURDEN TOTAL DEPTH 396.0 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Used 4-3/4" rock bit with air 0.0' to 6.0'	4-3/4" RB								6.0			0.0 to 6.0 Sand, fine, silty, clayey, firm, brown. (Logged from cuttings)
Set 4" casing to 6.0'	NX H	100							8.0			6.0 to 8.0 Sandstone, fine grained, limy, grey.
		100							13.0			8.0 to 13.0 Shale, clayey, silty, firm, brown stained, grey; slakes on drying.
Cored with NX metal bit and double tube core barrel 6.0' to 201.0'. Drilled without coring 4-3/4". 201.0' to 396.0' core in 2' to 8' lengths. Broken in boxing.		100							25.4			13.0 to 25.4 Sandstone, fine grained, silty, clayey, limy, little carbon. gypsum crystals on partings, laminated, grey
									28.0			25.4 to 28.0 Coal.
									30.4			28.0 to 30.4 Shale, clayey, some carbon firm, black.
												30.4 to 32.0 Coal.
		100							36.3			32.0 to 36.3 Shale, clayey, carbonaceous, firm, crumbly, black.
		100							47.0			36.3 to 47.0 Siltstone, clayey, fine sandy, can be cut with fingernail, massive, grey; softens on wetting, and sandstone 44.0 to 46.0.
Coal fell apart when picked up for sacking. Shale softens on wetting and slakes on drying.		100 / 100 / 100							69.4			47.0 to 69.4 Sandstone, fine grained, silty, weakly cemented, easily crushed with pliers, laminated, light grey.
									70.0			69.4 to 70.0 Coal, shaly (Not sampled).
		100							78.4			70.0 to 78.4 Shale, clayey, firm, fissile, many slickensides, dark grey; slakes on drying.
		100 / 100							94.7			78.4 to 94.7 Coal.
USBR personnel and drill rig, Failing 1500		100										94.7 to 105.0 Siltstone, clayey, firm, easily broken by hand, fissile, grey; limy zone at 106.7.

EXPLANATION

CORE LOSS

CORE RECOVERY

RB= Rock Bit

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series) . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (Y series). Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Table D-2 (con.)

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Bisti - West PROJECT B.L.M. STATE New Mexico

HOLE NO DH 7 LOCATION T23N, R12W, Sec. 8 NE¼,NE¼,NW¼ GROUND ELEV 5945± DIP (ANGLE FROM HORIZ.) 90°

COORDS. N E

BEGUN FINISHED DEPTH OF OVERBURDEN TOTAL DEPTH 396.0 ft BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED Not Measured LOGGED BY K. Cooper LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	NX H	100										Siltstone (continued)
		100							105.0			105.0 to 138.2 Sandstone, fine grained silty, little carbon weakly cemented, easily crushed with pliers, massive, grey, brown 125.0 to 126.5.
		100										
		100										
		100							138.2			138.2 to 138.6 Coal.
		100							138.6			138.6 to 157.4 Shale, clayey, coaly 141.2 to 141.8, firm, dark grey; slakes on drying.
Use of drilling mud prevented measuring water level. Hole was deepened to 396.0'. 2" diameter plastic pipe perforated below 200' was installed 8-14-75.		100							157.4			157.4 to 162.5 Coal.
		100							162.5			162.5 to 174.4 Shale, clayey, coaly 162.5 to 163.0, firm, fissile, dark grey, slakes on drying.
Drilling mud prevented logging cuttings 201.0' to 396.0'.		100							174.4			174.4 to 179.2 Sandstone, silty, weakly cemented, easily crushed with pliers, grey.
		100										179.2 to 185.1 Coal.
		100							185.1			185.1 to 188.2 Shale, clayey, firm, dark grey.
												188.2 to 191.3 Coal.
		100										191.3 to 196.3 Siltstone, coaly 191.3 to 191.7 clayey, fine sandy, firm, dark grey.
									196.3			196.3 to 201.0 Sandstone, siltstone, and shale.
	200								201.0			

Interpretive Notes

0-6' : Alluvium

6'-196.3': Fruitland Formation

Fruitland Formation - Pictured Cliffs Formation contact at 196.3'

EXPLANATION

Reamed 4-3/4" to 201.0. Drilled without coring 201.0 to 396.0. Hole was electrically logged by U.S.C.S.

CORE LOSS

CORE RECOVERY

Type of hole D = Diamond, H = Hoystellite, S = Shot, C = Churn

Hole sealed P = Packer, Cm = Cemented, Cs = Bottom of casing

APPENDIX E

COAL RESOURCES

Contents

Tables

Figures

Coal Beds Depths and Thicknesses */

Along the north-south line bisecting sections 6 and 7, seven beds of coal in the Fruitland Formation were cored in DH-1 between depths of 193.8 and 359.5 feet. These beds have a total thickness of 52.4 feet. The first two beds, in descending order, are: .7 and 1.3 feet thick, respectively, and are considered commercially unimportant. The third bed is 2.9 feet thick and lies between depths of 238.8 and 241.7 feet below the surface. The fourth and fifth beds are 20 and 18.5 feet thick and are separated by 2.5 feet of shale. These beds lie between depths of 297.5 and 338.5 feet. The sixth bed of coal is 7 feet thick and is separated from the fifth bed by 7.7 feet of shale. The seventh bed of coal between depths 357.5 and 359.5 feet may be commercially important.

In DH-2 eight beds of coal were found, having a total thickness of 32.8 feet. The first two beds between depths 38.4 and 39.6 feet and 47.7 and 48.9 feet, respectively, are commercially unimportant. The third bed is 5.5 feet thick and lies between depths of 96.5 and 102.0 feet. The remaining five beds are at depths between 113.0 and 164.0 feet. They range from 3.5 to 6.6 feet in thickness and are separated by shale and siltstone.

In DH-3 four beds of coal ranging from 4.2 to 7.7 feet thick, totaling 21.7 feet, were cored between depths of 53.4 and 116.9 feet. In DH-4 four beds of coal ranging from 2.1 to 10.0 feet thick, totaling 22.1 feet, were cored between depths 24.6 and 71.4 feet. The three upper beds of coal in DH-1 and the two upper beds in DH-2 were not found in DH-3 and DH-4 and are believed to have been removed by erosion.

Along the north-south line bisecting section 8, eight beds of coal ranging from .4 to 16.3 feet in thickness and totaling 35.6 feet were cored in DH-7. The upper three beds in descending order between depths 25.4 and 70.0 feet, were 2.6, 1.6, and .6 foot thick. The fourth bed is about 16.3 feet thick between depths of 78.4 and 94.7 feet. The fifth bed is .4 foot thick between depths 132.8 and 138.6 feet. The lower three beds are 5.1, 5.9, and 3.1 feet thick between depths 157.4 and 191.3 feet.

In DH-6 nine beds of coal ranging from 0.8 to 5.8 feet in thickness and totaling 26.7 feet were present between depths of 16.3 and 147.5 feet. In DH-5 two beds of coal were present and, in descending order, are 6.9 feet thick between depths 57.1 and 64.0 feet, and 6.2 feet thick between depths 74.8 and 81.0 feet. Coal cored in DH-5 was harder than most coal found in the other drill holes. The upper beds of coal found in DH-7 and DH-6 have been removed by erosion at DH-5.

*/ This narrative prepared by Bureau of Reclamation.

Table E-1

Summary of estimated identified coal resources of the area around and including the Bisti West EMRIA site

[In thousands of tons]

	Overburden thickness (feet)			
	0-200	200-1,000	More than 1,000	Total
Coal beds 2½ to 5 feet thick				
Measured resources	5,067	1,430	-	6,497
Indicated resources	8,151	5,370	-	13,521
Inferred resources	-----	-----	-	------
Total	13,218	6,800	-	20,018
Coal beds 5 to 10 feet thick				
Measured resources	15,580	3,134	-	18,714
Indicated resources	38,501	18,609	-	57,110
Inferred resources	7,931	------	-	7,931
Total	62,012	21,743	-	83,755
Coal beds more than 10 feet thick				
Measured resources	7,742	10,991	-	18,733
Indicated resources	19,342	25,992	-	45,334
Inferred resources	6,603	------	-	6,603
Total	33,687	36,983	-	70,670
Total identified resources	108,917	65,526	-	174,443

Table E-2

Estimated coal resources of the Bisti West area, T. 23 N., R. 12 W., New Mexico, around and including the EMRIA study site

(In thousands of tons)

Sec.	Zone*	0 - 200 feet of overburden												200 - 1,000 feet of overburden												Grand total
		2 1/2 - 5 feet				5 - 10 feet				10 feet and over				2 1/2 - 5 feet				5 - 10 feet				10 feet and over				
		Meas.	Indic.	Infer.	Total	Meas.	Indic.	Infer.	Total	Meas.	Indic.	Infer.	Total	Meas.	Indic.	Infer.	Total	Meas.	Indic.	Infer.	Total	Meas.	Indic.	Infer.	Total	
5	5	83	85	-	168	---	---	-	---	-	---	-	---	717	2,324	-	3,041	170	-----	-	170	-----	-----	-	-----	3,379
	4	---	---	-	---	---	106	-	106	-	835	-	835	147	613	-	760	---	3,241	-	3,241	193	2,161	-	2,354	7,296
	3	---	---	-	---	225	477	-	702	-	---	-	---	67	1,216	-	1,283	413	2,804	-	3,217	-----	1,068	-	1,068	6,270
	2	57	78	-	135	---	237	-	237	-	---	-	---	182	643	-	825	265	2,892	-	3,157	1,236	3,625	-	4,861	9,215
	1	125	---	-	125	---	377	-	377	-	---	-	---	---	183	-	183	456	3,859	-	4,315	1,659	2,773	-	4,432	9,432
	Total	265	163	-	428	225	1,197	-	1,422	-	835	-	835	1,113	4,979	-	6,087	1,304	12,796	-	14,100	3,088	9,627	-	12,715	35,592
6	5	---	---	-	---	---	-----	-	-----	-----	-----	-	-----	---	--	-	---	-----	-----	-	-----	-----	-----	-	-----	-----
	4	204	36	-	240	94	881	-	975	-----	-----	-	-----	296	33	-	329	168	1,466	-	1,634	-----	-----	-	-----	3,178
	3	---	---	-	---	---	-----	-	-----	1,508	3,412	-	4,920	---	--	-	---	-----	-----	-	-----	4,306	8,442	-	12,748	17,668
	2	---	--	-	---	---	669	-	669	1,230	2,016	-	3,246	---	--	-	---	-----	322	-	322	3,597	7,663	-	11,260	15,497
	1	---	--	-	---	938	2,227	-	3,165	-----	-----	-	-----	---	--	-	---	1,662	3,923	-	5,585	-----	-----	-	-----	8,750
	Total	204	36	-	240	1,032	3,777	-	4,809	2,738	5,428	-	8,166	296	33	-	329	1,830	5,711	-	7,541	7,903	16,105	-	24,008	45,093
7	5	-----	-----	-	-----	-----	-----	-	-----	---	-----	-	-----	-	-	-	-	-	-	-	-	-	-	-	-	-----
	4	109	425	-	534	-----	484	-	484	---	-----	-	-----	-	-	-	-	-	-	-	-	-	-	-	-	1,018
	3	1,090	1,506	-	2,596	1,003	2,598	-	3,601	712	-----	-	712	-	-	-	-	-	-	-	-	-	-	-	-	6,909
	2	-----	-----	-	-----	3,817	5,701	-	9,518	---	-----	-	-----	-	-	-	-	-	-	-	-	-	-	-	-	9,518
	1	-----	-----	-	-----	4,044	2,891	-	6,935	---	3,783	-	3,783	-	-	-	-	-	-	-	-	-	-	-	-	10,718
	Total	1,199	1,931	-	3,130	8,864	11,674	-	20,538	712	3,783	-	4,495	-	-	-	-	-	-	-	-	-	-	-	-	28,163
8	5	307	167	-	474	-----	-----	-	-----	-----	-----	-	-----	--	102	-	102	-	---	-	---	-	---	-	---	576
	4	140	260	-	400	735	2,470	-	3,205	3,082	2,047	-	5,129	--	---	-	---	-	102	-	102	-	260	-	260	9,096
	3	419	1,072	-	1,491	1,413	1,904	-	3,317	-----	-----	-	-----	--	130	-	130	-	---	-	---	-	---	-	---	4,938
	2	1,262	2,166	-	3,428	798	1,081	-	1,879	-----	-----	-	-----	--	---	-	---	-	---	-	---	-	---	-	---	5,307
	1	1,025	2,138	-	3,163	-----	-----	-	-----	-----	-----	-	-----	21	126	-	147	-	---	-	---	-	---	-	---	3,310
	Total	3,153	5,803	-	8,956	2,946	5,455	-	8,401	3,082	2,047	-	5,129	21	358	-	379	-	102	-	102	-	260	-	260	23,227
17	5	-	-	-	-	---	-----	-----	-----	-	-	-----	-----	-	-	-	-	-	-	-	-	-	-	-	-	-----
	4	-	-	-	-	---	-----	-----	-----	-	-	-----	-----	-	-	-	-	-	-	-	-	-	-	-	-	-----
	3	-	-	-	-	---	-----	-----	-----	-	-	-----	-----	-	-	-	-	-	-	-	-	-	-	-	-	-----
	2	-	-	-	-	757	5,524	2,199	8,480	-	-	1,643	1,643	-	-	-	-	-	-	-	-	-	-	-	-	10,123
	1	-	-	-	-	682	4,185	2,343	7,210	-	-	-----	-----	-	-	-	-	-	-	-	-	-	-	-	-	7,210
	Total	-	-	-	-	1,439	9,709	4,542	15,690	-	-	1,643	1,643	-	-	-	-	-	-	-	-	-	-	-	-	17,333
18	5	---	---	-	---	-----	-----	-----	-----	-----	-----	-----	-----	-	-	-	-	-	-	-	-	-	-	-	-	-----
	4	---	---	-	---	-----	-----	-----	-----	-----	-----	-----	-----	-	-	-	-	-	-	-	-	-	-	-	-	-----
	3	246	218	-	464	-----	-----	-----	-----	-----	-----	-----	-----	-	-	-	-	-	-	-	-	-	-	-	-	464
	2	---	---	-	---	-----	1,280	-----	1,280	1,210	6,419	4,960	12,589	-	-	-	-	-	-	-	-	-	-	-	-	13,869
	1	---	---	-	---	1,074	5,409	3,389	9,872	-----	830	-----	830	-	-	-	-	-	-	-	-	-	-	-	-	10,702
	Total	246	218	-	464	1,074	6,689	3,389	11,152	1,210	7,249	4,960	13,419	-	-	-	-	-	-	-	-	-	-	-	-	25,035
Total for area		5,067	8,151	-	13,218	15,580	38,501	7,931	62,012	7,742	19,342	6,603	33,687	1,430	5,370	-	6,800	3,134	18,609	-	21,743	10,991	25,992	-	36,983	174,443

*Coal zone numbered in ascending order from the Pictured Cliffs sandstone upward.

Table E3 .--Proximate, ultimate, Btu, and forms-of-sulfur analyses of 20 coal samples of Fruitland coal (Cretaceous age) from Bisti West EMRIA Site, San Juan County, New Mexico.

[All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: 1, as received; 2, moisture free; 3, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.] *Means composite

Drill Hole No.	Sample	Interval-feet	Form of analysis	Proximate analysis: Moisture	Vol.Mtr.	Fixed C	Ash	Ultimate analysis: Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur
DH-2	D176820	96.5-101.0	1	17.8	33.0	31.4	17.8	5.7	49.5	0.9	25.5	0.6
			2	-	40.1	38.2	21.7	4.5	60.2	1.1	11.8	.7
			3	-	51.2	48.8	-	5.8	76.9	1.4	15.0	.9
DH-2	D176821	101.0-102.0, 103.7-111.0	1	20.2	31.0	34.7	14.1	5.8	51.0	1.0	27.6	.5
			2	-	38.8	43.5	17.7	4.5	63.9	1.3	12.1	.6
			3	-	47.2	52.8	-	5.4	77.6	1.5	14.7	.8
DH-2	D176822	113.0-119.6	1	16.2	32.7	34.2	16.9	5.6	51.2	1.1	24.6	.6
			2	-	39.0	40.8	20.2	4.5	61.1	1.3	12.2	.7
			3	-	48.9	51.1	-	5.7	76.5	1.6	15.2	.9
DH-2	D176823	132.3-137.0, 138.0-141.0	1	22.3	29.6	31.2	16.9	5.8	46.9	.9	29.1	.4
			2	-	38.1	40.2	21.8	4.3	60.4	1.2	11.9	.5
			3	-	48.7	51.3	-	5.5	77.1	1.5	15.3	.7
DH-2	D176824	141.0-143.1	1	13.4	30.5	31.6	24.5	5.2	47.5	.8	21.6	.4
			2	-	35.2	36.5	28.3	4.3	54.8	.9	11.2	.5
			3	-	49.1	50.9	-	6.0	76.5	1.3	15.6	.6
DH-2	D176825*	149.5-151.0	1	17.9	31.9	35.8	14.4	5.9	52.1	1.0	26.2	.4
			2	-	38.9	43.6	17.5	4.8	63.5	1.2	12.5	.5
			3	-	47.1	52.9	-	5.8	77.0	1.5	15.2	.6
DH-2	D176827	160.5-164.0	1	19.0	30.4	29.7	20.9	5.4	46.8	1.0	25.4	.5
			2	-	37.5	36.7	25.8	4.1	57.8	1.2	10.5	.6
			3	-	50.6	49.4	-	5.5	77.9	1.7	14.2	.8
DH-1	D177032	238.7-241.7	1	11.0	27.0	26.5	35.5	4.5	39.5	1.0	18.6	.9
			2	-	30.3	29.8	39.9	3.7	44.4	1.1	9.9	1.0
			3	-	50.5	49.5	-	6.1	73.8	1.9	16.5	1.7
DH-1	D177033*	297.5-302.0	1	17.9	29.5	32.3	20.3	5.7	46.9	1.0	25.7	.4
			2	-	35.9	39.3	24.7	4.5	57.1	1.2	11.9	.5
			3	-	47.7	52.3	-	6.0	75.9	1.6	15.8	.6
DH-1	D177035*	320.4-330.0	1	15.5	21.8	22.5	40.2	4.4	32.5	.7	21.8	.4
			2	-	25.8	26.6	47.6	3.2	38.5	.8	9.5	.5
			3	-	49.2	50.8	-	6.0	73.4	1.6	18.1	.9

Table E3.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of 20 coal samples of Fruitland coal (Cretaceous age) from Bisti West EMRIA site, San Juan County, New Mexico.--Continued

Drill Hole No.	Sample	Interval-feet	Form of analysis	Proximate analysis: Moisture	Vol.Mtr.	Fixed C	Ash	Ultimate analysis: Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur
DH-1	D177037*	346.0-350.0	1	16.4	26.5	33.6	23.5	5.2	46.2	1.0	23.7	.4
			2	-	31.7	40.2	28.1	4.0	55.3	1.2	10.9	.5
			3	-	44.1	55.9	-	5.6	76.9	1.7	15.2	.7
DH-3	D177039	53.4-57.7	1	16.2	24.9	21.8	37.1	4.8	34.2	.8	22.6	.5
			2	-	29.7	26.0	44.3	3.6	40.8	1.0	9.8	.6
			3	-	53.3	46.7	-	6.4	73.2	1.7	17.6	1.1
DH-3	D177040	81.8-89.5	1	20.4	29.0	36.9	13.7	6.0	51.0	1.1	27.8	.4
			2	-	36.4	46.4	17.2	4.7	64.1	1.4	12.1	.5
			3	-	44.0	56.0	-	5.7	77.4	1.7	14.7	.6
DH-3	D177041	100.0-105.5	1	22.3	27.9	35.0	14.8	6.0	48.4	.9	29.5	.4
			2	-	35.9	45.0	19.0	4.5	62.3	1.2	12.5	.5
			3	-	44.4	55.6	-	5.6	76.9	1.4	15.4	.6
DH-3	D177042	113.7-116.9	1	25.0	28.5	33.3	13.2	6.3	48.1	.6	31.4	.4
			2	-	38.0	44.4	17.6	4.7	64.1	.8	12.2	.5
			3	-	46.1	53.9	-	5.7	77.8	1.0	14.9	.6
DH-4	D177043	40.3-48.0	1	17.4	30.2	39.2	13.2	5.9	54.1	1.2	25.1	.5
			2	-	36.6	47.5	16.0	4.8	65.5	1.5	11.7	.6
			3	-	43.5	56.5	-	5.7	78.0	1.7	13.9	.7
DH-4	D177044	60.3-64.9	1	14.5	30.9	36.5	18.1	5.4	51.4	1.1	23.5	.5
			2	-	36.1	42.7	21.2	4.4	60.1	1.3	12.4	.6
			3	-	45.8	54.2	-	5.6	76.3	1.6	15.7	.7
DH-4	D177045	69.2-71.4	1	11.1	23.5	24.6	38.8	4.3	37.5	.8	18.2	.4
			2	-	26.4	27.7	43.6	3.4	42.2	.9	9.4	.4
			3	-	46.9	49.1	-	6.1	74.9	1.6	16.6	.8
DH-7	D177046	30.4-32.0	1	16.1	22.7	18.4	42.8	4.5	29.7	.6	21.8	.8
			2	-	27.1	21.9	51.0	3.2	35.4	.7	8.9	1.0
			3	-	55.2	44.8	-	6.6	72.3	1.5	18.2	1.9
DH-7	D177047*	78.4-87.0	1	21.7	29.6	32.6	16.1	6.0	47.7	.9	28.9	0.4
			2	-	37.8	41.6	20.6	4.6	60.9	1.1	12.3	.5
			3	-	47.6	52.4	-	5.8	76.7	1.4	15.5	.6

Table E3.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of 20 coal samples of Fruitland coal (Cretaceous age) from Bisti West EMRIA site, San Juan County, New Mexico.--Continued

Drill Hole No.	Sample	Interval-feet	Form of analysis	Btu	A.d.loss	Forms of sulfur: Sulfate	Forms of sulfur: Pyritic	Forms of sulfur: Organic
DH-2	D176820	96.5-101.0	1	8760	10.9	0.01	0.09	0.51
			2	10660	-	.01	.11	.62
			3	13600	-	.02	.14	.79
DH-2	D176821	101.0-102.0, 103.7-111.0	1	8920	10.5	.01	.08	.42
			2	11180	-	.01	.10	.53
			3	13580	-	.02	.12	.64
DH-2	D176822	113.0-119.6	1	9030	7.3	.02	.06	.54
			2	10780	-	.02	.07	.64
			3	13500	-	.03	.09	.81
DH-2	D176823	132.3-137.0, 138.0-141.0	1	8230	13.7	.01	.03	.37
			2	10590	-	.01	.04	.48
			3	13540	-	.02	.05	.61
DH-2	D176824	141.0-143.1	1	8160	6.4	.01	.04	.38
			2	9420	-	.01	.05	.44
			3	13140	-	.02	.06	.61
DH-2	D176825*	149.5-151.0	1	9170	9.5	.01	.02	.38
			2	11170	-	.01	.02	.46
			3	13550	-	.01	.03	.56
DH-2	D176827	160.5-164.0	1	8130	10.3	.02	.04	.45
			2	10040	-	.02	.05	.56
			3	13530	-	.03	.07	.75
DH-1	D177032	238.7-241.7	1	6970	2.5	.01	.24	.62
			2	7830	-	.01	.27	.70
			3	13030	-	.02	.45	1.16
DH-1	D177033*	297.5-302.0	1	8260	10.3	.01	.02	.42
			2	10060	-	.01	.02	.51
			3	13370	-	.02	.03	.68
DH-1	D177035*	320.4-330.0	1	5610	8.0	.07	.05	.25
			2	6640	-	.08	.06	.30
			3	12660	-	.16	.11	.56

Table E3.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of 20 coal samples of Fruitland coal (Cretaceous age) from Bisti West EMRIA site, San Juan County, New Mexico.--Continued

Drill Hole No.	Sample	Interval-feet	Form of analysis	Btu	A.d.loss	Forms of sulfur: Sulfate	Forms of sulfur: Pyritic	Forms of sulfur: Organic
DH-1	D177037*	346.0-350.0	1	8150	10.2	0.02	0.04	0.35
			2	9750	-	.02	.05	.42
			3	13560	-	.03	.07	.58
DH-3	D177039	53.4-57.7	1	5980	10.8	.02	.08	.40
			2	7140	-	.02	.10	.48
			3	12810	-	.04	.17	.86
DH-3	D177040	81.8-89.5	1	8870	13.4	.02	.03	.37
			2	11140	-	.03	.04	.46
			3	13460	-	.03	.05	.56
DH-3	D177041	100.0-105.5	1	8440	14.4	.01	.06	.35
			2	10860	-	.01	.08	.45
			3	13420	-	.02	.10	.56
DH-3	D177042	113.7-116.9	1	8390	16.2	.01	.02	.39
			2	11190	-	.01	.03	.52
			3	13580	-	.02	.03	.63
DH-4	D177043	40.3-48.0	1	9340	7.8	.13	.05	.29
			2	11310	-	.16	.06	.35
			3	13460	-	.19	.07	.42
DH-4	D177044	60.3-64.9	1	9050	6.1	.11	.04	.33
			2	10580	-	.13	.05	.39
			3	13430	-	.16	.06	.49
DH-4	D177045	69.2-71.4	1	6640	5.2	.12	.02	.26
			2	7470	-	.13	.02	.29
			3	13250	-	.24	.04	.52
DH-7	D177046	30.4-32.0	1	5200	9.5	.10	.25	.43
			2	6200	-	.12	.30	.51
			3	12650	-	.24	.61	1.05
DH-7	D177047*	78.4-87.0	1	8340	14.6	.02	.03	.38
			2	10650	-	.03	.04	.49
			3	13410	-	.03	.05	.61

Table E-4.--Comparison of composition of Bisti West study site coal with composition of other San Juan River region coals

	Bisti West area (40 samples)	San Juan River Region[1/] (79 samples)
SiO_2 (in ash)	56 %	54 %
Na_2O (in ash)	1.64%	1.56%
CaO (in ash)	2.0 %	4.9 %
MgO (in ash)	.73%	.88%
As (whole coal)	2 ppm	3 ppm
B (whole coal)	70 ppm	100 ppm
Ba (whole coal)	500 ppm	300 ppm
Hg (whole coal)	.07 ppm	.12 ppm
Pb (whole coal)	12.9 ppm	13.1 ppm
U (whole coal)	3.2 ppm	2.5 ppm
Zn (whole coal)	19.3 ppm	15.1 ppm

1/ Hatch, J. R., and Swanson, V. E., 1976, Trace elements in Rocky and Northern Great Plains Coals, Proceedings volume, Rocky Mountain Coal Symposium (in press). To be published by the Colorado Geological Survey.

Table E5.--Major and minor oxide and trace element composition of the laboratory ash of 40 coal samples of Fruitland coal (Cretaceous age) from Bisti West EMRIA site, San Juan Co., N. Mex.

[Values are in either percent or parts per million. The coals were ashed at 525°C. L after a value means less than the value shown, N means not detected, and B means not determined. S after the element title means that the values listed were determined by semiquantitative spectrographic analysis. The spectrographic results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as mid-points of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of the spectrographic data is approximately one bracket at 68 percent, or two brackets at 95 percent confidence]

Drill Hole No.	Sample	Interval-feet	Ash %	SiO2 %	Al2O3 %	CaO %	MgO %	Na2O %	K2O %	Fe2O3 %	MnO %	TiO2 %
DH-1	177032	238.7-241.7	42.9	51	27	1.8	0.58	1.07	1.1	2.7	0.059	0.97
DH-1	177033	297.5-302.0	34.9	56	25	1.9	.60	.95	.91	1.8	.050L	1.0
DH-1	177034	302.0-317.5	17.1	51	26	2.3	.50	1.58	.57	2.5	.050L	1.2
DH-1	177035	320.4-330.0	42.9	50	26	3.9	.55	1.08	.59	2.3	.059	.68
DH-1	177036	330.0-338.0	46.9	61	17	2.3	.91	1.15	1.9	2.5	.050L	.71
DH-1	177037	346.0-350.0	16.9	49	22	1.9	.80	2.11	.54	3.8	.050L	.85
DH-1	177038	350.0-353.2, 357.5-359.5	32.2	73	12	.86	.38	1.03	.49	1.5	.051	.70
DH-2	176820	96.5-101.0	25.8	57	20	2.7	.41	1.36	.41	1.2	.050L	1.0
DH-2	176821	101.0-102.0, 103.7-111.0	18.1	54	25	2.8	.53	2.09	.32	3.2	.050L	1.1
DH-2	176822	113.0-119.6	38.4	52	24	4.4	.66	1.36	.60	2.7	.050L	.76
DH-2	176823	132.3-137.0, 138.0-141.0	35.0	57	29	1.2	.61	1.16	.82	2.7	.050L	.77
DH-2	176824	141.0-143.1	28.7	52	30	1.2	.66	1.21	.36	3.4	.050L	.99
DH-2	176825	149.5-151.0	38.6	63	20	.89	1.26	1.38	2.1	3.4	.050L	.73
DH-2	176826	151.0-156.0	18.9	55	27	1.9	.63	1.69	.61	2.6	.050L	.93
DH-2	176827	160.5-164.0	34.6	44	15	2.0	1.29	1.30	.98	15	.77	.53
DH-3	177039	53.4-57.7	36.4	54	26	1.2	.55	1.53	.74	1.7	.050L	.80
DH-3	177040	81.8-89.5	24.0	51	25	1.6	.68	1.61	.73	3.0	.050L	.82
DH-3	177041	100.0-105.5	21.7	50	23	2.4	.75	1.81	.62	2.7	.050L	.84
DH-3	177042	113.7-116.9	19.3	69	13	1.8	.56	1.69	.50	2.3	.050L	.73
DH-4	177043	40.3-48.0	16.5	50	24	2.5	.75	2.39	.35	3.2	.050L	.97
DH-4	177044	60.3-64.9	27.3	55	24	1.3	.86	1.74	1.1	2.6	.050L	.86
DH-4	177045	69.2-71.4	16.5	55	21	2.0	.70	2.15	.43	2.2	.050L	.86
DH-5	178928	57.1-64.0	15.8	57	20	2.8	.81	2.40	.32	3.7	.018	.96
DH-5	178929	74.8-81.0	17.0	52	23	2.6	.85	2.50	.62	3.8	.014	.81
DH-6	178919	16.3-20.6	28.5	56	25	2.6	.75	2.32	.61	2.2	.019	.84
DH-6	178920	24.1-26.2	31.5	62	21	1.3	1.10	1.61	2.3	2.7	.023	.78
DH-6	178921	34.6-40.5	19.7	51	28	2.1	.56	1.80	.41	2.5	.010	1.0
DH-6	178922	66.9-68.0	43.2	62	24	.82	.78	1.48	.93	2.4	.005	.67
DH-6	178923	87.8-88.6	29.9	70	13	2.9	.55	1.31	.46	2.3	.022	.74
DH-6	178924	93.3-99.1	21.2	57	22	2.4	.76	1.88	.75	3.9	.011	.73
DH-6	178925	133.8-138.4	15.6	57	25	2.3	.66	2.15	.37	4.5	.014	.87
DH-6	178926	141.9-142.8, 146.3-147.5	32.9	62	23	1.1	.91	1.44	1.3	2.8	.015	.76
DH-7	178914	25.4-28.0	42.5	58	18	1.5	1.03	1.67	1.2	3.3		.60
DH-7	177046	30.4-32.0	46.8	55	22	1.5	.65	1.17	1.7	4.0		.76
DH-7	177047	78.4-87.0	23.8	50	27	2.5	.55	1.46	.81	2.1		1.0
DH-7	177048	87.4-94.7	17.4	49	24	3.1	.53	2.12	.38	2.5	.052	1.1
DH-7	178915	136.2-138.6	42.9	58	21	.87	.96	1.58	1.2	2.6	.009	.64
DH-7	178916	157.4-162.5	14.4	54	22	2.7	.81	2.50	.54	3.7	.014	.90
DH-7	178917	179.2-185.1	22.6	61	22	1.4	.80	1.65	1.4	2.5	.012	.81
DH-7	178918	188.2-191.3	32.8	64	21	1.1	.81	1.34	1.3	2.8	.012	.77

Table E5.--Major and minor oxide and trace element composition of the laboratory ash of 40 coal samples of fruitland coal (Cretaceous age) from Bisti West EMRIA site, San Juan Co., N. Mex.--Continued

Sample	P2O5 %	SO3 %	Cl %	Cd ppm	Cu ppm	Li ppm	Pb ppm	Zn ppm	Ag ppm-S	B ppm-S
D177032	1.0 L	1.3	0.20 L	1.0	80	89	50	102	N	200
D177033	1.0 L	1.7	.20 L	1.0L	61	56	45	68	N	200
D177034	1.0 L	2.5	.20 L	1.0L	54	75	55	35	N	500
D177035	1.0 L	1.2	.20 L	1.0L	35	55	60	68	N	200
D177036	1.0 L	.75	.20 L	1.0L	38	31	35	76	N	300
D177037	1.0 L	2.6	.20 L	1.0L	47	108	55	37	N	500
D177038	1.0 L	1.1	.20 L	1.0L	34	70	30	36	N	200
D176820	1.0 L	1.5	.20 L	1.0L	66	112	45	52	1	300
D176821	1.0 L	2.6	.20 L	1.0L	62	111	45	35	N	500
D176822	1.0 L	1.2	.20 L	1.0L	48	55	50	79	N	150
D176823	1.0 L	.82	.20 L	1.0L	38	62	55	83	N	200
D176824	1.0 L	.82	.20 L	1.0L	48	47	45	128	N	200
D176825	1.0 L	.78	.20 L	1.0L	53	54	30	88	N	200
D176826	1.0 L	1.6	.20 L	1.0L	41	107	45	29	N	500
D176827	1.0 L	2.4	.20 L	1.0L	35	49	35	95	N	150
D177039	1.0 L	1.2	.20 L	1.0L	58	87	60	46	N	200
D177040	1.0 L	1.9	.20 L	1.0L	42	29	60	51	N	300
D177041	1.0 L	2.3	.20 L	1.0L	38	97	50	35	N	500
D177042	1.0 L	2.2	.20 L	1.0L	52	44	35	52	N	500
D177043	1.0 L	3.4	.20 L	1.0L	64	100	55	59	N	700
D177044	1.0 L	1.6	.20 L	1.0L	45	102	35	40	N	300
D177045	1.0 L	2.9	.20 L	1.0L	64	70	50	90	N	700
D178928	1.0 L	3.6	.20 L	1.0L	55	82	55	37	N	500
D178929	1.0 L	3.3	.20 L	1.0L	52	83	50	51	N	300
D178919	1.0 L	3.8	.20 L	1.0L	60	74	60	40	N	150
D178920	1.0 L	1.8	.20 L	1.0L	68	46	45	105	N	150
D178921	1.0 L	2.6	.20 L	1.0L	72	134	65	33	N	300
D178922	1.0 L	1.0	.20 L	1.0L	42	92	45	57	N	100
D178923	1.0 L	2.0	.20 L	1.0L	34	51	25	98	N	150
D178924	1.0 L	2.6	.20 L	1.0L	56	121	50	52	N	200
D178925	1.0 L	3.2	.20 L	1.0L	37	121	45	29	N	300
D178926	1.0 L	1.3	.20 L	1.0L	43	61	40	75	N	150
D178914	1.0 L	1.3	.20 L	1.0L	47	40	30	82	N	100
D177046	1.0 L	1.5	.20 L	1.0L	72	42	35	102	N	150
D177047	1.0 L	2.9	.20 L	1.0L	90	116	60	66	N	500
D177048	1.0 L	3.1	.20 L	1.0L	81	171	75	31	N	700
D178915	1.0 L	.98	.20 L	1.0L	37	62	35	95	N	100
D178916	1.0 L	3.1	.20 L	1.0L	59	103	60	49	N	500
D178917	1.0 L	1.7	.20 L	1.0L	37	86	45	64	N	300
D178918	1.0 L	1.2	.20 L	1.0L	39	50	50	56	N	150

Table E5.--Major and minor oxide and trace element composition of the laboratory ash of coal samples of fruitland coal (Cretaceous age) from Bisti West EMRIA site, San Juan Co., N. Mex.--Continued

Sample	Ba ppm-S	Be ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Ga ppm-S	Ge ppm-S	La ppm-S	Mo ppm-S	Nb ppm-S
D177032	700	15	N	10	30	50	N	N	10	N
D177033	5000	7	N	10	50	50	N	N	10	20
D177034	7000	10	N	10	50	70	N	N	10	30
D177035	3000	7	N	7	15	50	N	N	7	20
D177036	3000	10	500 L	15	150	100	N	100	7	30
D177037	2000	30	500 L	10	50	50	30	100 L	7	20
D177038	700	15	N	15	20	20	N	N	N	20
D176820	3000	15	N	15	30	30	N	N	7	30
D176821	5000	10	500 L	15	30	50	N	100 L	7	30
D176822	3000	7	500 L	15	20	30	N	100 L	10	30
D176823	1500	7	500 L	15	30	30	N	100 L	7	30
D176824	700	15	500 L	15	20	30	N	100	7	30
D176825	700	15	500 L	15	50	30	N	100 L	N	30
D176826	700	10	N	10	30	50	N	100 L	15	30
D176827	700	15	500 L	15	30	30	N	100 L	N	20 L
D177039	1000	10	N	7	20	70	N	N	10	20
D177040	2000	10	N	10	20	70	N	N	7	20
D177041	2000	15	N	7	30	70	N	100 L	7	30
D177042	700	30	N	10	50	50	30	N	N	20
D177043	2000	15	N	10	30	70	N	100 L	15	30
D177044	1000	7	N	7	50	50	N	N	N	30
D177045	1000	70	N	50	50	70	300	100 L	N	30
D178928	2000	20	N	10	30	30	N	100 L	7	30
D178929	1500	15	N	10	15	30	N	N	7	20
D178919	1000	15	N	7	20	50	N	N	5	20
D178920	700	15	N	20	20	30	N	N	5	20
D178921	500	10	N	10	20	50	N	N	7	30
D178922	500	20	N	5	20	50	N	N	5	20
D178923	700	50	N	15	20	30	50	N	5	30
D178924	1000	20	N	10	20	50	20	100 L	5	20
D178925	1000	50	N	15	20	50	30	100 L	7	30
D178926	500	20	N	10	30	30	N	100 L	N	20
D178914	500	10	N	5	20	30	N	N	N	20
D177046	1000	10	N	10	20	50	N	100 L	15	20 L
D177047	1500	7	N	7	30	70	N	N	15	20
D177048	1500	10	N	10	50	70	N	N	15	30
D178915	1000	15	N	15	20	50	30	N	5	20
D178916	3000	15	N	10	20	50	N	N	10	20
D178917	700	15	N	10	20	30	N	N	N	20
D178918	500	15	N	7	30	50	N	N	N	20

Table E5 .-- Major and minor oxide and trace element composition of the laboratory ash of coal samples of fruitland coal (Cretaceous age) from Bisti West EMRIA site, San Juan Co., N. Mex.--Continued

Sample	Nd ppm-S	Ni ppm-S	Sc ppm-S	Sr ppm-S	V ppm-S	Y ppm-S	Yb ppm-S	Zr ppm-S
D177032	B	10	15	5000	200	50	5	200
D177033	B	10	15	300	200	20	3	200
D177034	B	15	15	500	150	50	5	300
D177035	B	7	10	200	70	50	3	200
D177036	150 L	30	50	700	300	70	7	300
D177037	N	15	20	500	150	100	10	300
D177038	B	10	10	150	70	70	5	200
D176820	B	20	15	300	150	30	3	300
D176821	150 L	30	20	300	150	70	7	500
D176822	N	15	15	300	100	50	5	300
D176823	150 L	15	15	200	100	50	5	300
D176824	150 L	20	15	150	100	70	7	700
D176825	N	30	20	150	150	70	7	200
D176826	N	15	15	300	150	70	7	500
D176827	N	15	15	200	70	70	7	200
D177039	B	7	15	200	100	20	3	200
D177040	B	10	15	500	100	30	3	200
D177041	N	10	15	500	100	50	5	200
D177042	B	20	15	300	100	70	7	200
D177043	N	20	15	700	150	50	5	200
D177044	B	15	20	300	150	50	5	200
D177045	N	70	30	500	150	150	15	300
D178928	N	20	15	500	100	70	7	500
D178929	B	20	10	500	70	50	5	200
D178919	B	10	10	300	70	30	3	200
D178920	B	20	10	200	100	70	7	150
D178921	B	15	10	300	100	50	5	300
D178922	B	7	7	150	70	50	5	150
D178923	B	20	10	200	70	100	10	150
D178924	N	15	10	300	70	70	7	200
D178925	N	20	15	300	100	70	7	300
D178926	N	15	15	200	100	100	7	200
D178914	B	10	10	200	100	20	2	150
D177046	N	15	15	300	200	50	5	200
D177047	B	7	15	500	150	30	3	200
D177048	B							

Table E6.--Major, minor, and trace element composition of 40 coal samples of Fruitland Coal (Cretaceous age) from Bisti West EMRIA Site, San Juan County, New Mexico.

[Values are in either percent or parts per million. Si, Al, Ca, Mg, Na, K, Fe, Mn, Ti, P, Cl, Cd, Cu, Li, Pb, and Zn values were calculated from analysis of ash. As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal. The remaining analyses were calculated from spectrographic determinations on ash. L after a value means less than the value shown, N means not detected, and B means not determined.]

Drill Hole No.	Sample	Interval-feet	Si %	Al %	Ca %	Mg %	Na %	K %	Fe %	Mn ppm	Ti %	P ppm
DH-1	D177032	238.7-241.7	10	6.1	0.55	0.150	0.339	0.41	0.82	200	0.25	1800 L
DH-1	D177033	297.5-302.0	9.1	4.6	.48	.126	.244	.27	.44	140 L	.21	1500 L
DH-1	D177034	302.0-317.5	4.1	2.4	.28	.051	.200	.081	.30	66 L	.13	750 L
DH-1	D177035	320.4-330.0	10	5.8	1.2	.142	.343	.21	.68	200	.18	1800 L
DH-1	D177036	330.0-338.0	13	4.1	.77	.258	.399	.73	.83	180 L	.20	2000 L
DH-1	D177037	346.0-350.0	3.9	2.0	.23	.081	.264	.077	.45	65 L	.086	740 L
DH-1	D177038	350.0-353.2,357.5-359.5	11	2.1	.20	.074	.245	.13	.33	130	.13	1400 L
DH-2	D176820	96.5-101.0	6.8	2.7	.50	.065	.261	.089	.21	100 L	.16	1100 L
DH-2	D176821	101.0-102.0, 103.7-111.0	4.6	2.3	.36	.058	.281	.049	.40	70 L	.12	790 L
DH-2	D176822	113.0-119.6	9.4	4.9	1.2	.154	.388	.19	.73	150 L	.17	1600 L
DH-2	D176823	132.3-137.0, 138.0-141.0	9.3	5.4	.31	.129	.301	.24	.67	140 L	.16	1500 L
DH-2	D176824	141.0-143.1	6.9	4.5	.24	.115	.258	.086	.69	110 L	.17	1200 L
DH-2	D176825	149.5-151.0	11	4.1	.25	.293	.394	.69	.91	150 L	.17	1600 L
DH-2	D176826	151.0-156.0	4.9	2.7	.25	.072	.236	.096	.35	73 L	.10	820 L
DH-2	D176827	160.5-164.0	7.2	2.8	.49	.270	.332	.28	3.7	2000	.11	1500 L
DH-3	D177039	53.4-57.7	9.3	4.9	.31	.120	.411	.23	.42	140 L	.17	1500 L
DH-3	D177040	81.8-89.5	5.7	3.2	.27	.098	.286	.15	.51	93 L	.12	1000 L
DH-3	D177041	100.0-105.5	5.1	2.7	.37	.098	.291	.11	.41	84 L	.11	950 L
DH-3	D177042	113.7-116.9	6.2	1.3	.25	.066	.241	.081	.30	75 L	.085	840 L
DH-4	D177043	40.3-48.0	3.8	2.1	.30	.074	.292	.048	.37	64 L	.095	720 L
DH-4	D177044	60.3-64.9	7.0	3.5	.26	.142	.352	.25	.49	110 L	.14	1100 L
DH-4	D177045	69.2-71.4	4.2	1.9	.24	.069	.262	.059	.26	64 L	.085	720 L
DH-5	D178928	57.1-64.0	4.2	1.7	.32	.077	.281	.042	.41	22	.091	690 L
DH-5	D178929	74.8-81.0	4.2	2.1	.32	.087	.314	.088	.45	19	.082	740 L
DH-6	D178919	16.3-20.6	7.4	3.7	.53	.128	.490	.14	.44	43	.14	1200 L
DH-6	D178920	24.1-26.2	9.1	3.5	.30	.208	.375	.60	.60	57	.15	1300 L
DH-6	D178921	34.6-40.5	4.7	2.9	.30	.067	.262	.067	.35	16	.12	860 L
DH-6	D178922	66.9-68.0	13	5.4	.25	.203	.475	.33	.73	17	.17	1800 L
DH-6	D178923	87.8-88.6	9.8	2.0	.62	.099	.290	.12	.48	51	.13	1300 L
DH-6	D178924	93.3-99.1	5.6	2.5	.36	.098	.295	.13	.57	18	.093	930 L
DH-6	D178925	133.8-138.4	4.2	2.0	.26	.062	.248	.048	.27	16	.081	680 L
DH-6	D178926	141.9-142.8, 146.3-147.5	9.5	4.0	.26	.181	.352	.35	.65	38	.15	1400 L
DH-7	D178914	25.4-28.0	12	4.0	.47	.264	.527	.42	.98	76	.15	1800 L
DH-7	D177046	30.4-32.0	12	5.4	.51	.183	.407	.67	1.3	210	.21	2000 L
DH-7	D177047	78.4-87.0	5.5	3.4	.43	.079	.257	.16	.35	98	.15	1000 L
DH-7	D177048	87.4-94.7	4.0	2.2	.38	.056	.273	.054	.31	71	.12	760 L
DH-7	D178915	136.2-138.6	12	4.9	.27	.249	.502	.42	.79	30	.16	1800 L
DH-7	D178916	157.4-162.5	3.6	1.7	.28	.071	.266	.065	.38	16	.078	630 L
DH-7	D178917	179.2-185.1	6.5	2.7	.23	.108	.276	.27	.40	20	.11	990 L
DH-7	D178918	188.2-191.3	9.8	3.7	.25	.161	.325	.35	.64	30	.15	1400 L

Table E6.--Major, minor, and trace element composition of 40 coal samples of Fruitland Coal (Cretaceous age) from Bisti West EMRIA Site, San Juan County, New Mexico.—Continued

Sample	As ppm	F ppm	Hg ppm	Sb ppm	Se ppm	Th ppm	U ppm
D177032	6	85	0.20	2.2	2.3	3.0L	4.4
D177033	2	90	.17	.7	2.0	3.0L	3.8
D177034	1	45	.03	.4	1.8	3.0L	2.7
D177035	1	135	.17	.6	1.9	12.4	3.9
D177036	2	55	.08	.6	1.3	3.0L	3.0
D177037	1	30	.02	1.5	1.4	3.0L	2.4
D177038	1	20 L	.03	1.3	1.5	5.8	2.6
D176820	2	30	.04	.8	3.0	15.7	2.3
D176821	1	95	.11	.7	2.2	11.3	2.3
D176822	2	145	.19	1.4	2.2	24.8	4.7
D176823	1	65	.09	.8	2.7	3.0L	3.1
D176824	1	50	.08	1.8	1.9	15.9	4.7
D176825	2	85	.05	1.4	1.7	13.6	2.3
D176826	1	60	.02	.5	1.9	12.7	1.8
D176827	2	85	.06	.9	1.7	9.5	2.3
D177039	1	80	.05	1.0	2.3	11.5	3.7
D177040	1	60	.03	.3	1.8	4.9	2.3
D177041	1	75	.10	1.1	1.3	3.0L	2.6
D177042	1	25	.03	2.1	1.3	3.0L	1.0
D177043	1	50	.03	.6	1.7	3.0L	2.6
D177044	1	105	.10	.7	1.3	6.5	2.6
D177045	1	25	.03	4.3	1.6	3.0L	1.9
D178928	1	20 L	.04	.8	1.1	3.0L	1.7
D178929	2	20 L	.04	.9	.6	6.3	2.3
D178919	2	20 L	.02	1.0	1.8	7.6	3.4
D178920	2	80	.07	1.4	1.1	6.7	4.3
D178921	1	20 L	.01	.7	1.7	5.5	3.6
D178922	4	65	.16	2.0	1.5	11.2	5.0
D178923	2	30	.10	2.9	1.0	3.0L	3.7
D178924	1	20 L	.08	1.0	1.4	5.0	2.2
D178925	1	20 L	.03	.8	.8	3.0L	2.3
D178926	2	55	.06	1.4	1.3	6.2	3.7
D178914	1	145	.06	1.4	.9	7.4	3.0
D177046	32	115	.26	6.5	1.8	15.1	9.4
D177047	1	80	.06	1.0	2.5	3.0L	3.6
D177048	1	65	.04	.6	2.3	7.8	2.5
D178915	2	70	.13	2.0	1.5	3.0L	5.4
D178916	1	20 L	.01	.4	1.5	7.3	1.3
D178917	1	45	.02	.6	1.1	5.7	2.6
D178918	1	40	.03	.9	1.4	6.8	3.1

Table E6 .--Major, minor, and trace element composition of 40 coal samples of Fruitland Coal (Cretaceous age) from Bisti West EMRIA Site, San Juan County, New Mexico.--Continued

Sample	Cl %	As ppm	Cd ppm	Cu ppm	F ppm	Hg ppm	Li ppm	Pb ppm	Sb ppm	Se ppm
D177032	0.086L	6	0.43	34.3	85	0.20	38.2	21.4	2.2	2.3
D177033	.070L	2	.35L	21.3	90	.17	19.5	15.7	.7	2.0
D177034	.034L	1	.17L	9.2	45	.03	12.8	9.4	.4	1.8
D177035	.086L	1	.43L	15.0	135	.17	23.6	25.7	.6	1.9
D177036	.094L	2	.47L	17.8	55	.08	14.5	16.4	.6	1.3
D177037	.034L	1	.17L	7.9	30	.02	18.3	9.3	1.5	1.4
D177038	.064L	1	.32L	10.9	20 L	.03	22.5	9.7	1.3	1.5
D176820	.052L	2	.26L	17.0	30	.04	28.9	11.6	.8	3.0
D176821	.036L	1	.18L	11.2	95	.11	20.1	8.1	.7	2.2
D176822	.077L	2	.38L	18.4	145	.19	21.1	19.2	1.4	2.2
D176823	.070L	1	.35L	13.3	65	.09	21.7	19.2	.8	2.7
D176824	.057L	1	.29L	13.8	50	.08	13.5	12.9	1.8	1.9
D176825	.077L	2	.39L	20.5	85	.05	20.8	11.6	1.4	1.7
D176826	.038L	1	.19L	7.7	60	.02	20.2	8.5	.5	1.9
D176827	.069L	2	.35L	12.1	85	.06	17.0	12.1	.9	1.7
D177039	.073L	1	.36L	21.1	80	.05	31.7	21.8	1.0	2.3
D177040	.048L	1	.24L	10.1	60	.03	7.0	14.4	.3	1.8
D177041	.043L	1	.22L	8.2	75	.10	21.0	10.9	1.1	1.3
D177042	.039L	1	.19L	10.0	25	.03	8.5	6.8	2.1	1.3
D177043	.033L	1	.16L	10.6	50	.03	16.5	9.1	.6	1.7
D177044	.055L	1	.27L	12.3	105	.10	27.8	9.6	.7	1.3
D177045	.033L	1	.16L	10.6	25	.03	11.5	8.2	4.3	1.6
D178928	.032L	1	.16L	8.7	20 L	.04	13.0	8.7	.8	1.1
D178929	.034L	2	.17L	8.8	20 L	.04	14.1	8.5	.9	.6
D178919	.057L	2	.28L	17.1	20 L	.02	21.1	17.1	1.0	1.8
D178920	.063L	2	.31L	21.4	80	.07	14.5	14.2	1.4	1.1
D178921	.039L	1	.20L	14.2	20 L	.01	26.4	12.8	.7	1.7
D178922	.086L	4	.43L	18.1	65	.16	39.7	19.4	2.0	1.5
D178923	.060L	2	.30L	10.2	30	.10	15.2	7.5	2.9	1.0
D178924	.042L	1	.21L	11.9	20 L	.08	25.7	10.6	1.0	1.4
D178925	.031L	1	.16L	5.8	20 L	.03	18.9	7.0	.8	.8
D178926	.066L	2	.33L	14.1	55	.06	20.1	13.2	1.4	1.3
D178914	.085L	1	.43L	20.0	145	.06	17.0	12.7	1.4	.9
D177046	.094L	32	.47L	33.7	115	.26	19.7	16.4	6.5	1.8
D177047	.048L	1	.24L	21.4	80	.06	27.6	14.3	1.0	2.5
D177048	.035L	1	.17L	14.1	65	.04	29.8	13.0	.6	2.3
D178915	.086L	2	.43L	15.9	70	.13	26.6	15.0	2.0	1.5
D178916	.029L	1	.14L	8.5	20 L	.01	14.8	8.6	.4	1.5
D178917	.045L	1	.23L	8.4	45	.02	19.4	10.2	.6	1.1
D178918	.066L	1	.33L	12.8	40	.03	16.4	16.4	.9	1.4

Table E6.--Major, minor, and trace element composition of 40 coal samples of Fruitland Coal (Cretaceous age) from Bisti West EMRIA Site, San Juan County, New Mexico.--Continued

Sample	Th ppm	U ppm	Zn ppm	Ag ppm-S	B ppm-S	Ba ppm-S	Be ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S
D177032	3.0L	4.4	43.8	N	100	300	7	N	5	15
D177033	3.0L	3.8	23.7	N	70	1500	2	N	3	15
D177034	3.0L	2.7	6.0	N	100	1000	1.5	N	1.5	10
D177035	12.4	3.9	29.2	N	100	1500	3	N	3	7
D177036	3.0L	3.0	35.6	N	150	1500	5	200 L	7	70
D177037	3.0L	2.4	6.3	N	100	300	5	100 L	1.5	10
D177038	5.8	2.6	11.6	N	70	200	5	N	5	7
D176820	15.7	2.3	13.4	.2	70	700	5	N	5	7
D176821	11.3	2.3	6.3	N	100	1000	2	100 L	3	5
D176822	24.8	4.7	30.3	N	70	1000	3	200 L	7	7
D176823	3.0L	3.1	29.0	N	70	500	2	150 L	5	10
D176824	15.9	4.7	36.7	N	70	200	5	150 L	5	7
D176825	13.6	2.3	34.0	N	70	300	7	200 L	7	20
D176826	12.7	1.8	5.5	N	100	150	2	N	2	7
D176827	9.5	2.3	32.9	N	50	200	5	150 L	5	10
D177039	11.5	3.7	16.7	N	70	300	3	N	2	7
D177040	4.9	2.3	12.2	N	70	500	2	N	2	5
D177041	3.0L	2.6	7.6	N	100	500	3	N	1.5	7
D177042	3.0L	1.0	10.0	N	100	150	7	N	2	10
D177043	3.0L	2.6	9.7	N	100	300	2	N	1.5	5
D177044	6.5	2.6	10.9	N	70	300	2	N	2	15
D177045	3.0L	1.9	14.9	N	100	150	10	N	7	7
D178928	3.0L	1.7	5.8	N	70	300	3	N	1.5	5
D178929	6.3	2.3	8.7	N	50	200	2	N	1.5	2
D178919	7.6	3.4	11.4	N	50	300	5	N	2	7
D178920	6.7	4.3	33.1	N	50	200	5	N	7	7
D178921	5.5	3.6	6.5	N	70	100	2	N	2	5
D178922	11.2	5.0	24.6	N	50	200	10	N	2	10
D178923	3.0L	3.7	29.3	N	50	200	15	N	5	7
D178924	5.0	2.2	11.0	N	50	200	5	N	2	5
D178925	3.0L	2.3	4.5	N	50	150	7	N	2	3
D178926	6.2	3.7	24.7	N	50	150	7	N	3	10
D178914	7.4	3.0	34.8	N	50	200	5	N	2	10
D177046	15.1	9.4	47.7	N	70	500	5	N	5	10
D177047	3.0L	3.6	15.7	N	100	300	1.5	N	1.5	7
D177048	7.8	2.5	5.4	N	150	200	1.5	N	1.5	10
D178915	3.0L	5.4	40.8	N	50	500	7	N	7	10
D178916	7.3	1.3	7.1	N	70	500	2	N	1.5	3
D178917	5.7	2.6	14.5	N	70	150	3	N	2	5
D178918	6.8	3.1	18.4	N	50	150	5	N	2	10

Table E6.--Major, minor, and trace element composition of 40 coal samples of Fruitland Coal (Cretaceous age) from Bisti West EMRIA Site, San Juan County, New Mexico.--Continued

Sample	Ga ppm-S	Ge ppm-S	La ppm-S	Mo ppm-S	Nb ppm-S	Nd ppm-S	Ni ppm-S	Sc ppm-S	Sr ppm-S	V ppm-S
D177032	20	N	N	5	N	B	5	7	2000	100
D177033	15	N	N	3	7	B	3	5	100	70
D177034	10	N	N	1.5	5	B	2	2	100	20
D177035	20	N	N	3	10	B	3	5	100	30
D177036	50	N	50	3	15	70 L	15	20	300	150
D177037	10	5	15 L	1	3	N	2	3	100	20
D177038	7	N	N	N	7	B	3	3	50	20
D176820	7	N	N	2	7	B	5	5	70	50
D176821	10	N	20 L	1.5	5	30 L	5	3	50	30
D176822	10	N	50 L	5	10	N	7	7	100	50
D176823	10	N	30 L	2	10	50 L	5	5	70	30
D176824	10	N	30	2	10	50 L	7	5	50	30
D176825	10	N	50 L	N	10	N	10	7	70	70
D176826	10	N	20 L	3	7	N	3	3	70	30
D176827	10	N	30 L	N	7 L	N	5	5	70	20
D177039	20	N	N	3	7	B	2	5	70	30
D177040	15	N	N	1.5	5	B	2	3	100	20
D177041	15	N	20 L	1.5	7	N	2	3	100	20
D177042	10	7	N	N	5	B	5	3	70	20
D177043	10	N	15 L	2	5	N	3	2	100	20
D177044	15	N	N	N	7	B	5	5	70	50
D177045	10	50	15 L	N	5	N	10	5	70	20
D178928	5	N	15 L	1	5	N	3	2	70	15
D178929	5	N	N	1	3	B	3	1.5	100	10
D178919	15	N	N	1.5	7	B	3	3	100	20
D178920	10	N	N	1.5	7	B	7	3	70	30
D178921	10	N	N	1.5	7	B	3	2	70	20
D178922	20	N	N	2	10	B	3	3	70	30
D178923	10	15	N	1.5	10	B	7	3	70	20
D178924	10	5	20 L	1	5	N	3	2	70	15
D178925	7	5	15 L	1	5	N	3	2	50	15
D178926	10	N	30 L	N	7	N	5	5	70	30
D178914	15	N	N	N	10	B	5	5	100	50
D177046	20	N	50 L	7	10 L	N	7	7	150	100
D177047	15	N	N	3	5	B	1.5	3	100	30
D177048	15	N	N	2	5	B	1.5	2	150	20
D178915	20	15	N	2	10	B	7	5	100	50
D178916	7	N	N	1.5	3	B	2	1.5	70	15
D178917	7	N	N	N	5	B	2	2	50	15
D178918	15	N	N	N	7	B	3	3	70	20

Table E6.--Major, minor, and trace element composition of 40 coal samples of Fruitland Coal (Cretaceous age) from Bisti West EMRIA Site, San Juan County, New Mexico.--Continued

Sample	Y ppm-S	Yb ppm-S	Zr ppm-S
D177032	20	2	100
D177033	7	1	70
D177034	10	1	50
D177035	20	1.5	100
D177036	30	3	150
D177037	15	1.5	50
D177038	20	1.5	70
D176820	7	.7	70
D176821	15	1.5	100
D176822	20	2	100
D176823	15	1.5	100
D176824	20	2	200
D176825	30	3	70
D176826	15	1.5	100
D176827	20	2	70
D177039	7	1	70
D177040	7	.7	50
D177041	10	1	50
D177042	15	1.5	50
D177043	7	.7	30
D177044	15	1.5	50
D177045	20	2	50
D178928	10	1	70
D178929	10	1	30
D178919	10	1	70
D178920	20	2	50
D178921	10	1	70
D178922	20	2	70
D178923	30	3	50
D178924	15	1.5	50
D178925	10	1	50
D178926	30	2	70
D178914	10	1	70
D177046	20	2	100
D177047	7	.7	50
D177048	5	.5	50
D178915	20	2	70
D178916	7	.7	30
D178917	10	1	50
D178918	20	2	50

COAL

Origin

Coal has been defined as follows:

> A readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade), are characteristics of the varities of coal (Schopf 1956).

Inherent in the definition is the specification that the coal originated as a mixture of organic plant remains and inorganic mineral matter that accumulated in a manner similar to that in which modern-day peat deposits are formed. The peat then underwent a long, extremely complex process called "coalification" during which diverse physical and chemical changes occurred as the peat changed to coal and the coal assumed the characteristics by which we differentiate members of the series from each other. The factors that affect the composition of coals have been summarized as follows (Francis 1961, page 2):

(1) The mode of accumulation and burial of the plant debris forming the deposit.

(2) The age of the deposits and their geographical distribution.

(3) The structure of the coal-forming plants, particularly details of structure that affect chemical composition or resistance to decay.

(4) The chemical composition of the coal-forming debris and its resistance to decay.

(5) The nature and intensity of the plant-decaying agencies.

(6) The subsequent geological history of the residual products of decay of the plant debris forming the deposits.

For extended discussion of these factors, the reader is referred to such standard works as Moore (1940), Lowry (1945), Tomkeieff (1954), Francis (1961), and Lowry (1963).

Classification

Coals can be classified in many ways (Tomkeieff, 1954, page 9; Moore, 1940, page 113; Francis, 1961, page 361), but the classification by

rank--that is by degree of metamorphism in the progressive series which begins with peat and ends with praphocite (Schopf 1966)--is the most commonly used system. Classification by types of plant materials is commonon used as a descriptive adjunct to rank classification when sufficient mega and microscopic information is available, and classification by type and quantity of impurities (grade) is also frequently used when utilization of the coal is being considered. Other categorizations are possible and are commonly employed in discussion of coal resources--such factors as the weight of the coal, the thickness and areal extent of the individual coal beds, and the thickness of overburden are generally considered.

Rank of coal

The position of a coal within the metamorphic series, which begins with peat and ends with graphocite, is dependent on the temperature and pressure to which the coal has been subjected and the duration of time of subjection. Because it is by definition largely derived from plant material, coal is mostly composed of carbon, hydrogen, and oxygen, along with smaller quantities of nitrogen, sulfur, and other elements. The increase in rank of coal as it undergoes progressive metamorphism is indicated by changes in the proportions of the coal constitutents--the higher rank coals have more carbon and less hydrogen than lower ranks.

Two standardized forms of coal analyses--the proximate analysis and the ultimate analysis--are generally used in the world today, though sometimes only the less complicated and less expensive proximate analysis is made. The analyses are described as follows (U.S. Bureau of Mines, 1965, pages 121-122):

> The proximate analysis of coal involves the determination of four constituents: (1) water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cakelike residue that burns at higher temperatures after volatile matter has been driven off. Ultimate analysis involves the determination of carbon and hydrogen as found in the gaseous products of combustion; the determination of sulfur, nitrogen, and ash in the material as a whole; and the estimation of oxygen by difference.

Most coals are burned to produce heat energy so the heating value of the coal is an important property. The heating value (calorific value) is commonly expressed in British thermal units (Btu) per pound; one Btu is the amount of heat required to raise the temperature of 1 pound of water 1 degree fahrenheit (in the metric system, heating value is expressed in kilogram-calories per kilogram). Additional tests are

sometimes made, particularly to determine the caking, coking, and other properties, such as tar yield, which affect classification or utilization.

Figure E-1 compares in histogram form the heating values and moisture, volatile matter, and fixed carbon contents of coals of different ranks.

Various schemes for classifying coals by rank have been proposed and used, but the most commonly employed are the "Standard specifications for classification of coals by rank," adopted by the American Society for Testing and Materials (1974).

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matter and the heating value supplemented by determination of agglomerating (caking) characteristics. As pointed out by the ASTM (1974, page 55), a standard rank determination cannot be made unless the samples were obtained in accordance with standardized sampling procedures (Snyder, 1950; Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank."

Type of coal

Classification of coals by type--that is, according to the types of plant materials present--takes many forms, such as the "rational analysis" of Francis (1961), or the semicommercial "type" classification commonly used in the coal fields of the eastern United States (U.S. Bureau of Mines, 1965, page 123). However, most of the type classifications are based on the same, or similar, gross distinctions in plant material used by Tomkeieff (1954, table II, and page 9), who divided the coals into three series: humic coals, humic-sapropelic coals, and sapropelic coals, based on the nature of the original plant materials. The humic coals are largely composed of the remains of the woody parts of plants and the sapropelic coals are largely composed of the more resistant waxy, fatty, and resinous parts of plants, such as cell walls, spore-coatings, pollen, resin particles, and coals composed mainly of algal material. Most coals fall into the humic series, with some coals being a mixture of humic and sapropelic elements and, therefore, falling into the humic-sapropelic series. The sapropelic series is quantitatively insignificant and when found is commonly regarded as an organic curiosity. In common with most of the United States coals, those from Bisti West fall largely in the humic series.

Grade of coal

Classification of coal by grade or quality is based largely on the content of ash, sulfur, and other constituents that adversely affect utilization. Most detailed coal resource evaluations of the past do not categorize known coal resources by grade but coals of the United States

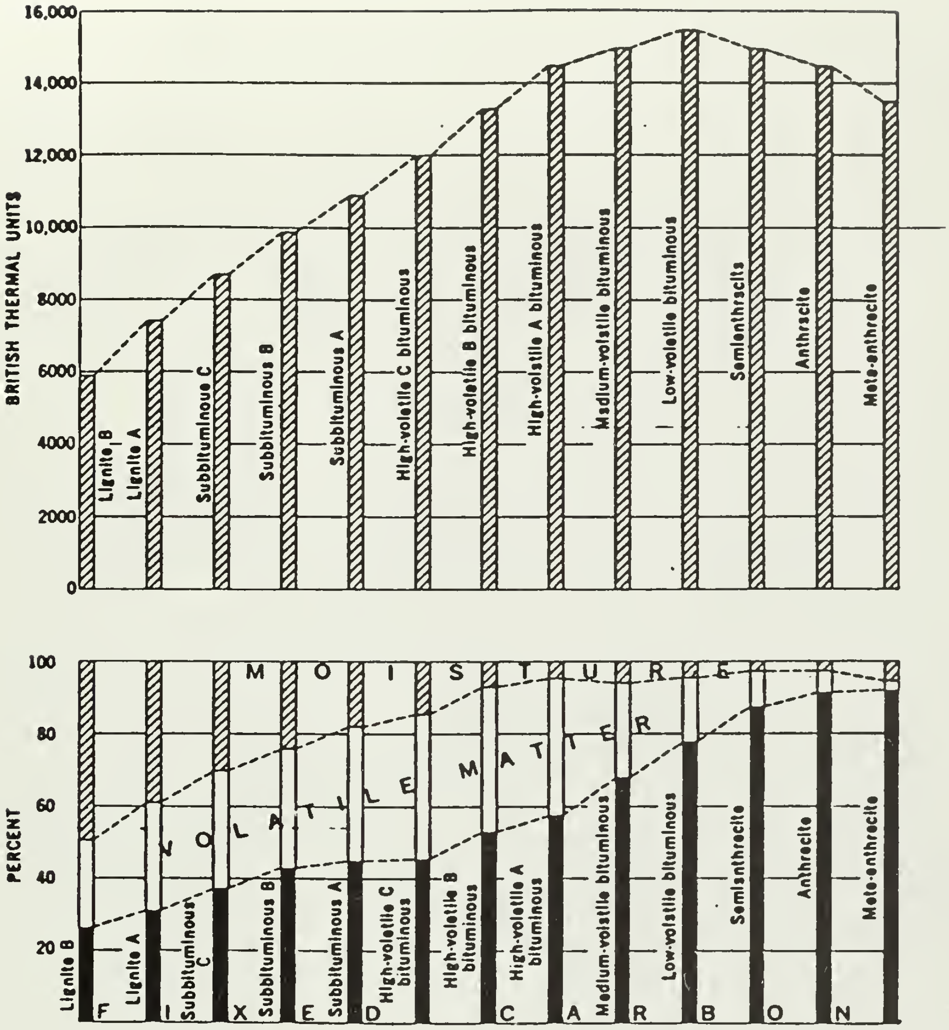

Figure E-1.--Comparison on moist, mineral-matter-free basis of heat values and proximate analyses of coal of different ranks.

have been classified by sulfur content in a gross way (DeCarlo and others, 1966).

The range and average of the ash and sulfur content of 642 coals from all parts of the United States were determined by Fieldner, Rice, and Moran (1942).

Ash and sulfur contents of United states coals as received:

Number of samples	Ash, percent		Sulfur, percent	
	Range	Average	Range	Average
642	2.5-32.6	8.9	0.2-7.7	1.9

APPENDIX F

HYDROLOGY

Tables

Figures

TABLE F-1.--SUSPENDED SEDIMENT ANALYSES OF SURFACE WATERS AT OR NEAR THE BISTI WEST RECLAMATION STUDY SITE

(Explanation: YMD, year-month-day; C, Celcius; CFS, cubic feet per second; MG/L, milligrams per liter; MM, millimeters; E, estimated)

DATE	TIME (2400 Clock)	TEMPERATURE (DEG C)	DISCHARGE (CFS)[a]	SUSPENDED SEDIMENT CONCEN-TRATION (MG/L)	SUSPENDED SEDIMENT DISCHARGE (tons/day)[a]	SUSPENDED SEDIMENT SIEVE DIAMETER %FINER THAN 0.0625MM	SUSPENDED SEDIMENT SIEVE DIAMETER %FINER THAN 0.250MM
COAL CREEK ABOVE TANNER LAKE, NEAR BISTI TRADING POST, NM (Map Site 37)							
750909	1200	15.5	E3	12,600	E100	100	--
ALAMO WASH NR TANNER LAKE, NM (Map Site 38)							
741031	--	--	E500	67,300	E91,000	96	--
750908	--	--	E500	144,000	E190,000	67	--
750908	1410	20.0	E5	50,700	E680	100	--
750912	1330	--	E2	21,100	E170	100	--
DE-NA-ZIN WASH NR BISTI TRADING POST, NM (Map Site 35)							
750313	1215	5.5	E0.3	28,900	E23	100	--
750710	0945	26.5	E7	20,500	E390	99	--
750710	1145	--	E5	12,600	E170	68	--
750711	0945	26.5	E10	23.700	E640	95	--
750813	1220	29.5	E.5	11,100	E15	99	--
750903	1650	19.0	E10	29,300	E790	99	--
750909	1030	--	E5	26,600	E360	99	--
750909	1300	22.0	E1	55,700	E150	100	--
750911	1300	--	E5	14,900	E200	100	--
750912	1100	20.0	E3	12,600	E100	99	--
750912	1130	--	E1	5,630	E15	75	--

a. Discharge rate at instantaneous time of measurement or sampling in the channel.

TABLE F-1.--(Continued)

DATE (YMD)	TIME (2400 Clock)	TEMPERATURE (DEGC)	DISCHARGE (CFS)[a]	SUSPENDED SEDIMENT CONCEN- TRATION (MG/L)	SUSPENDED SEDIMENT DISCHARGE (tons/day)[a]	SUSPENDED SEDIMENT SIEVE DIAMETER %FINER THAN 0.0625MM	SUSPENDED SEDIMENT SIEVE DIAMETER %FINER THAN 0.250MM
HUNTER WASH TRIBUTARY AT ROAD CROSSING SOUTH OF BISTI TRADING POST, NM (Map Site 65)							
750412 or 750413	--	--	E20	27,400	E1500	99	--
750710	1315	--	E7	43,600	E820	96	--
750710	E1900	--	E20	33,800	E1800	98	--
750710	E1905	--	E50	49,100	E6600	93	--
750711	--	--	E20	55,900	E3000	79	--
750909	E0900	19.0	E2.0	44,700	E241	100	--
750912	E1500	--	E20	40,500	E2200	99	--
750912	E1505	--	E50	152,000	E21.000	97	--
HUNTER WASH AT BISTI TRADING POST, NM (Map Site 33)							
741031	--	--	E110	177,000	53,000	58	--
741031	--	--	E410	206,000	230,000	48	--
750413	1030	--	2.1	41,100	233	98	--
750414	1030	--	.03	50,900	4.1	98	--
750709	1700	--	.10	57,000	16	83	--
		--	E110	148,000	44,000	67	--
			E410	168,000	190,000	65	--
750710	1145	29.5	.01	11,900	.32	74	--
750711	1330	--	.52	50,200	70	100	--
750711	1510	31.0	.34	9,350	8.6	100	--
750715	1000	15.0	.30	30,100	2.4	98	--
750715	1600	--	.01	31,500	.85	94	--
750716	1100	14.0	71	28,900	5,540	99	--
750716	1600	15.0	2.1	28,300	160	99	--
750717	1000	15.5	.52	30,100	42	99	--
750717	1400	15.5	.10	28,600	7.7	99	--
750812	0930	--	.10	6,660	1.8	100	--

a. Discharge rate at instantaneous time of measurement or sampling in the channel.

TABLE F-1.--(Concluded)

DATE (YMD)	TIME (2400 Clock)	TEMPERATURE (DEGC)	DISCHARGE (CFS)[a]	SUSPENDED SEDIMENT CONCEN-TRATION (MG/L)	SUSPENDED SEDIMENT DISCHARGE (tons/day)[a]	SUSPENDED SEDIMENT SIEVE DIAMETER %FINER THAN 0.0625MM	SUSPENDED SEDIMENT SIEVE DIAMETER %FINER THAN 0.250MM
HUNTER WASH AT BISTI TRADING POST, NM (con't)							
750812	1430	--	.10	6,360	1.7	100	--
750903	1630	--	18	4,750	231	---	--
750904	1130	--	0.1	4,880	1.3	--	--
750905	1100	--	0.1	12,300	3.3	--	--
750905	1500	--	0.1	12,300	3.3	--	--
750908	1030	--	0.3	15,900	13	--	--
750908	1400	--	0.1	16,000	4.3	--	--
750909	1900	--	418	174,000	196,000	71[b]	100[b]
750911	1950	--	E110	96,600	E28,700	76	--
750911	2000	--	E410	253,000	E280,000	82	--
750911	2200	--	E65	E180,000	E31,600	32	--
750912	0900	14.5	3.2	26,200	226	94	--
750912	1100	--	2.8	26,800	203	--	--
750912	1500	--	1.7	29,300	134	--	--

a. Discharge rate at instantaneous time of measurement or sampling in channel.
b. Fall diameter of suspended sediment particles.

Table F-2.--Chemical analyses of surface waters at or near the Bisti West reclamation study site (analyses by the U. S. Geological Survey, unless otherwise noted) -

Explanation: mg/l, milligrams per liter; ug/l, micrograms per liter; JUT, Jackson turbitity units; specific conductance in micromhos per cm at 25°c

Analysis no.	Descriptive information
1	23N.12W.17.222 Coal Creek above Tanner Lake, NM (Map site 37) (trickle after peak)
2	23N.12W.20.314 Pond 1.4 miles south of Tanner Lake, NM Map site 74 (about 1.5 AF storage)
3	23N.12W.07.313 Side Wash 1.0 miles NW of Tanner Lake, NM Map site 70 (from pond in Wash)
4	23N.13W.24.340 Pond 2.0 miles SW of Tanner Lake, NM Map site 72 (shallow 0.25AF storage)
5	23N.13W.23.412 Pond 2.5 miles SW of Tanner Lake, NM Map site 71 (about 3 AF storage)
6	

Item	Analysis number					
	1	2[a]	3	4[b]	5	6
Date of sample, YMD	750821	760330	750409	760330	750722	
Time, 2400 clock	1700	1345	1130	1430	1500	
Geologic Unit	--	--	--	--	--	
Depth of sampling interval, ft	--	--	--	--	--	
Discharge, cfs (00061)	0.10	--	0.01	--	--	
Silica (SiO_2), mg/l (00955)	8.3	4.0	7.8	0.3	0.7	
Iron (Fe), ug/l (01046)	150	40	100	110	100	
Calcium (Ca), mg/l (00915)	26	40	15	150	55	
Magnesium (Mg), mg/l (00925)	2.3	5.4	1.3	18	3.7	
Sodium (Na), mg/l (00930)	140	130	170	790	120	
Potassium (K), mg/l) (00935)	5.4	16	7.1	19	15	
Bicarbonate (HCO_3), mg/l (00440)	248	345	296	365	89	
Carbonate (CO_3), mg/l (00445)	0	0	0	0	3	
Sulfate (SO_4), mg/l (00945)	160	93	170	1800	320	
Chloride (Cl), mg/l (00940)	8.6	23	15	28	3.6	
Fluoride (F), mg/l (00950)	1.2	1.1	0.9	0.8	0.5	
Nitrite+Nitrate (N), mg/l (00631)	2.7	2.0	8.0	1.0	2.8	
Orthophosphate (P), mg/l (00671)	0.01	0.02	0.00	0.02	0.00	
Dissolved solids, Sum, mg/l (70301)	486	492	569	2990	578	
Total hardness ($CaCO_3$), mg/l (00900)	74	120	43	450	150	
NC hardness ($CaCO_3$), mg/l (00902)	0	0	0	150	75	
S.A.R. (00931)	7.1	5.1	11	16	4.2	
Specific conductance (00095)	755	750	862	4000	846	
pH, standard units (00400)	8.1	7.4	8.3	7.5	8.6	
Temperature, water, °C (00010)	24.0	6.5	1.5	14.0	29.5	
Aluminum, Total, ug/l (01105)	--	--	--	--	--	
Arsenic, Total, ug/l (01002)	160	4	38	6	--	
Boron, dissolved, ug/l (01020)	140	140	40	350	--	
Boron, Total, ug/l (01022)	--	--	--	--	--	
Lead, Total, ug/l (01051)	--	--	--	--	--	
Lithium, Total, ug/l (01132)	--	--	--	--	--	
Mercury, Total, ug/l (71900)	--	0.0	0.4	0.0	--	
Selenium, Total, ug/l (01147)	4	1	4	7	--	
Sulfide, Total, mg/l (00745)	--	--	--	--	--	
Carbon, Total Organic, mg/l (00680)	--	--	--	--	--	

a/ Other Values: Cadmium, total, 10 ug/l; chromium, total, o ug/l; copper, total, 10 ug/l; turbidity, 220 JTU.

b/ Other Values: Cadmium, total, 10 ug/l; chromium, total, o ug/l; copper, total, 30 ug/l; turbidity, 150 JTU.

TABLE F-2.--Chemical analyses of surface waters at or near the Bisti West reclamation study site - continued

Analysis no. this page	Descriptive information This page: 09367710 De-Na-Zin Wash near Bisti Trading Post, NM (Map site 35)
1	(collected from runoff ponded on upstream edge of road crossing)
2	(recession of small flow event)
3	(trickle from very local runoff)
4	
5	
6	

Item	Analysis number					
	1	2	3	4	5	6
Date of sample, YMD	740812	750313	750710			
Time, 2400 clock	1500	1215	0945			
Geologic Unit	--	--	--			
Depth of sampling interval, ft	--	--	--			
Discharge, cfs (00061)	<0.1	0.3	7			
Silica (SiO_2), mg/l (00955)	12	1.7	14			
Iron (Fe), ug/l (01046)	80	1400	1300			
Calcium (Ca), mg/l (00915)	16	3.3	12			
Magnesium (Mg), mg/l (00925)	1.3	0.8	1.4			
Sodium (Na), mg/l (00930)	140	95	140			
Potassium (K), mg/l) (00935)	3.2	1.4	5.2			
Bicarbonate (HCO_3), mg/l (00440)	240	124	304			
Carbonate (CO_3), mg/l (00445)	0	0	0			
Sulfate (SO_4), mg/l (00945)	140	100	120			
Chloride (Cl), mg/l (00940)	12	3.1	8.6			
Fluoride (F), mg/l (00950)	1.7	0.9	1.0			
Nitrite+Nitrate (N), mg/l (00631)	1.4	0.8	3.7			
Orthophosphate (P), mg/l (00671)	0.04	0.07	0.12			
Dissolved solids, Sum, mg/l (70301)	451	273	470			
Total hardness ($CaCO_3$), mg/l (00900)	45	12	36			
NC hardness ($CaCO_3$), mg/l (00902)	0	0	0			
S.A.R. (00931)	9.1	12	10			
Specific conductance (00095)	734	480	690			
pH, standard units (00400)	7.7	8.0	8.1			
Temperature, water, °C (00010)	25.0	5.5	26.5			
Aluminum, Total, ug/l (01105)	--	--	--			
Arsenic, Total, ug/l (01002)	39	28	--			
Boron, dissolved, ug/l (01020)	70	30	--			
Boron, Total, ug/l (01022)	--	--	--			
Lead, Total, ug/l (01051)	--	--	--			
Lithium, Total, ug/l (01132)	--	--	--			
Mercury, Total, ug/l (71900)	0.0	0.4	--			
Selenium, Total, ug/l (01147)	3	5	--			
Sulfide, Total, mg/l (00745)	--	--	--			
Carbon, Total Organic, mg/l (00680)	--	--	--			

Table F-2.--Chemical analyses of surface waters at or near the Bisti West reclamation study site - continued

Analysis no. (this page)	Descriptive information This page: 09367730 Hunter Wash at Bisti Trading Post, NM (Map Site 33)
1	(recession of flow event with peak discharge of 200 cfs)
2	(trickle in channel after small flow event with peak discharge of 6 cfs)
3	(just after peak of flow event with peak discharge of 10 cfs)
4	(trickle in channel after small flow event with peak discharge of 18 cfs)
5	(sampled at peak of flow event with peak discharge of 18 cfs)
6	(composite sample for radiochemical analyses - see foot notes for values)

Item	Analysis number					
	1	2	3	4	5	6 [c]
Date of sample, YMD	750711	750714	750716	750812	750903	7509(04-12)
Time, 2400 clock	1330	1015	1100	1430	1630	--
Geologic Unit	--	--	--	--	--	--
Depth of sampling interval, ft	--	--	--	--	--	--
Discharge, cfs (00061)	0.52	0.15	71	0.10	18	--
Silica (SiO_2), mg/l (00955)	16	17	15	13	12	--
Iron (Fe), ug/l (01046)	--	--	--	--	--	--
Calcium (Ca), mg/l (00915)	36	41	43	9.6	22	--
Magnesium (Mg), mg/l (00925)	2.4	3.7	3.9	0.9	4.2	--
Sodium (Na), mg/l (00930)	280	340	250	120	110	--
Potassium (K), mg/l) (00935)	5.8	6.3	4.2	3.6	3.8	--
Bicarbonate (HCO_3), mg/l (00440)	65	139	202	167	156	--
Carbonate (CO_3), mg/l (00445)	23	0	0	0	0	--
Sulfate (SO_4), mg/l (00945)	640	710	470	160	110	--
Chloride (Cl), mg/l (00940)	9.8	21	10	9.7	8.5	--
Fluoride (F), mg/l (00950)	1.0	1.5	1.0	1.2	0.9	--
Nitrite+Nitrate (N), mg/l (00631)	0.89	4.0	6.4	1.9	1.7	--
Orthophosphate (P), mg/l (00671)	--	--	--	--	--	--
Dissolved solids, Sum, mg/l (70301)	1050	1230	925	409	356	500
Total hardness ($CaCO_3$), mg/l (00900)	100	120	120	28	72	--
NC hardness ($CaCO_3$), mg/l (00902)	8	4	0	0	0	--
S.A.R. (00931)	12	14	9.8	9.9	5.6	--
Specific conductance (00095)	1530	1780	1360	622	511	760
pH, standard units (00400)	9.8	7.6	7.9	8.3	7.5	8.0
Temperature, water, °C (00010)	--	--	14.0	--	--	--
Aluminum, Total, ug/l (01105)	--	--	--	--	--	--
Arsenic, Total, ug/l (01002)	--	--	--	--	--	--
Boron, dissolved, ug/l (01020)	80	110	90	170	210	--
Boron, Total, ug/l (01022)	--	--	--	--	--	--
Lead, Total, ug/l (01051)	--	--	--	--	--	--
Lithium, Total, ug/l (01132)	--	--	--	--	--	--
Mercury, Total, ug/l (71900)	--	--	--	--	--	--
Selenium, Total, ug/l (01147)	--	--	--	--	--	--
Sulfide, Total, mg/l (00745)	--	--	--	--	--	--
Carbon, Total Organic, mg/l (00680)	--	--	--	--	--	--

c/ Other values in picocuries per liter (pc/l): gross alpha dissolved, 11; gross alpha suspended 2100; gross beta dissolved as cesium-137, 8.5; gross beta suspended as cesium-137, 690; potassium-40 dissolved, 4.0; radium-226 by radon method, 0.06; uranium dissolved, 3.4 ug/l; dissolved solids, 500 mg/l; suspended solids, 25000 mg/l.

Table F-2.--Chemical analyses of surface waters at or near the Bisti West reclamation study site - concluded

Analysis no. this page	Descriptive information This page: 09367730 Hunter Wash at Bisti Trading Post, NM (Map site 33)
1	(after peak of flow event with peak discharge of 90 cfs)
2	(after peak of small flow event with peak discharge of 24 cfs)
3	(at end of above flow event)
4	(rising stage of flow event with peak discharge of 500 cfs-sample used for radiochemical analyses)
5	(recession of flow event with peak discharge of 510 cfs)
6	(trickle from snowmelt of recent storm - very turbid sample)

Item	Analysis number					
	1	2	3	4	5	6[d]
Date of sample, YMD	750905	750908	750908	750908	750912	760129
Time, 2400 clock	1100	1030	1400	1650	1015	--
Geologic Unit	--	--	--	--	--	--
Depth of sampling interval, ft	--	--	--	--	--	--
Discharge, cfs (00061)	0.1	0.3	0.1	--	3.0	<0.1
Silica (SiO_2), mg/l (00955)	16	20	21	--	12	12
Iron (Fe), ug/l (01046)	--	--	--	--	--	16000
Calcium (Ca), mg/l (00915)	4.7	8.2	8.0	--	14	38
Magnesium (Mg), mg/l (00925)	1.4	0.6	1.0	--	1.1	6.2
Sodium (Na), mg/l (00930)	98	180	170	--	140	110
Potassium (K), mg/l) (00935)	2.9	3.8	4.2	--	2.6	5.5
Bicarbonate (HCO_3), mg/l (00440)	162	183	136	--	179	191
Carbonate (CO_3), mg/l (00445)	0	0	0	--	0	0
Sulfate (SO_4), mg/l (00945)	92	220	230	--	180	52
Chloride (Cl), mg/l (00940)	6.2	12	18	--	9.4	--
Fluoride (F), mg/l (00950)	0.7	0.9	1.1	--	1.1	0.3
Nitrite+Nitrate (N), mg/l (00631)	2.4	4.9	4.9	--	0.45	1.4
Orthophosphate (P), mg/l (00671)	--	--	--	--	--	10
Dissolved solids, Sum, mg/l (70301)	313	558	542	--	451	~300
Total hardness ($CaCO_3$), mg/l (00900)	18	23	24	--	40	120
NC hardness ($CaCO_3$), mg/l (00902)	0	0	0	--	0	0
S.A.R. (00931)	10	16	15	--	9.7	4.4
Specific conductance (00095)	469	859	855	1650	700	435
pH, standard units (00400)	8.2	7.6	7.5	--	7.9	7.6
Temperature, water, °C (00010)	--	--	--	--	--	--
Aluminum, Total, ug/l (01105)	--	--	--	--	--	--
Arsenic, Total, ug/l (01002)	--	--	--	--	--	37
Boron, dissolved, ug/l (01020)	140	200	210	--	80	220
Boron, Total, ug/l (01022)	--	--	--	--	--	~220
Lead, Total, ug/l (01051)	--	--	--	--	--	--
Lithium, Total, ug/l (01132)	--	--	--	--	--	80
Mercury, Total, ug/l (71900)	--	--	--	--	--	0.4
Selenium, Total, ug/l (01147)	--	--	--	--	--	3
Sulfide, Total, mg/l (00745)	--	--	--	--	--	--
Carbon, Total Organic, mg/l (00680)	--	--	--	--	--	27

d/ Other value in micrograms per liter (ug/l): Cadmium total, 10; chromium total, 50; copper total, 170; iron total, 92000; manganese total, 1800; suspended sediment; 23000 mg/l.

Table F-3

GROUND WATER-BEARING UNITS NEAR THE BISTI WEST RECLAMATION STUDY SITE

Geologic Unit	Depth (ft)	Direction of flow	Rate of flow	Yield	Chemical Quality	Potential for supply
Kirtland-Fruitland fm	Surface-250 ft	West	<10 ft/yr (estimated)	<10 gpm (estimated)	poor; spec. cond. >3,000 µmhos;exceeds 10,000 µmhos in places	very poor
Pictured Cliffs sandstone	Surface-500 ft	Northwest	<10 ft/yr (estimated)	<10 gpm (estimated)	very poor; spec. cond. >10,000 µmhos; high, Na, SO_4	very poor
Cliff house sandstone	Surface-1,000 ft	Northwest	<10 ft/yr (estimated)	<10 gpm (estimated)	poor; spec. cond. >2,000 µmhos	poor
Menefee formation	500-1,500 ft	Northwest	<10 ft/yr (estimated)	<10 gpm (estimated)	poor; spec. cond. >5,000 µmhos	poor
Point Lookout sandstone	2,300-3,300 ft	No data but probably Northwest	No data but probably <10 ft/vr	No data but probably <10 gpm	No data but spec. cond. probably >2,000 µmhos	poor
Gallup sandstone	3,000-4,000 ft	Northwest	<20 ft/yr (estimated)	<50 gpm (estimated)	fair in other areas; poor in study area; spec.cond.>4,000 µmhos	poor to fair
Morrison formation	4,500-5,500 ft	Northwest	<20 ft/yr (estimated)	<50 gpm but may be as high as 500 gpm	good to poor; spec. cond. range 1,000->6,000 µmhos.	fair to good
Entrada sandstone	5,000-6,000 ft	Unknown	<20 ft/yr (estimated)	<50 gpm (estimated)	poor; spec. cond. >5,000 µmhos; exceeds 20,000 µmhos in places	poor

Table F-4.-Chemical analyses of ground waters at or near the Bisti West reclamation study site (analyses by the U.S. Geological Survey unless otherwise noted)-

Explanation: mg/l, milligrams per liter; ug/l, micrograms per liter; JTU, Jackson turbidity units; specific conductance in micromhos per centimeter at 25°C.

Geologic units: PCCF, Pictured Cliffs Formation; CLFH, Cliffhouse Sandstone; PNLK, Point Lookout Sandstone; GLLP, Gallup Sandstone; WSRC, Westwater Canyon Sandstone Member of Morrison Formation; ENRD; Entrada Sandstone.

Analysis no. This page	Descriptive information
1	23N.12W.05.221 Well 2.7 miles NE Tanner Lake, NM (converted gas test well) (Map site 67)
2	23N.12W.08.2111 DH7 observation well near Bisti TP, NM (Map site 41)
3	23N.12W.07.2333 DH3 observation well near Bisti TP, NM (Map site 42)
4	23N.12W.17.2111 DH5 observation well near Bisti TP, NM (Map site 40)
5	23N.12W.18.233 BIA 19T-507 well at Tanner Lake, NM (windmill) (Map site 75)
6	

Item	Analysis number					
	1[a]	2[b]	3[c]	4[d]	5[e]	6
Date of sample, YMD	760331	760331	751021	760331	760426	
Time, 2400 clock	1245	1130	1130	1030	1300	
Geologic Unit	PNLK	PCCF	PCCF	PCCF	CLFH	
Depth of sampling interval, ft	2556-2564	200-394	118-350	86-274	288-369	
Discharge, gpm	~5	(airlift)	(airlift)	(airlift)	~20	
Silica (SiO_2), mg/l (00955)	17	3.9	7.0	4.5	7.8	
Iron (Fe), ug/l (01046)	90	80	80	110	100	
Calcium (Ca), mg/l (00915)	9.5	12	4.1	11	3.5	
Magnesium (Mg), mg/l (00925)	2.7	3.0	3.2	2.0	1.2	
Sodium (Na), mg/l (00930)	2800	1600	1500	1200	790	
Potassium (K), mg/l) (00935)	14	9.2	9.9	5.4	3.2	
Bicarbonate (HCO_3), mg/l (00440)	2360	96	302	208	632	
Carbonate (CO_3), mg/l (00445)	0	0	129	8	62	
Sulfate (SO_4), mg/l (00945)	26	180	85	1600	890	
Chloride (Cl), mg/l (00940)	3100	2300	2000	590	73	
Fluoride (F), mg/l (00950)	5.3	2.1	1.5	4.0	1.5	
Nitrite+Nitrate (N), mg/l (00631)	0.04	0.03	0.28	0.04	0.53	
Orthophosphate (P), mg/l (00671)	0.04	0.00	0.00	0.00	0.02	
Dissolved solids, Sum, mg/l (70301)	7140	4160	3890	3530	2150	
Total hardness ($CaCO_3$), mg/l (00900)	35	42	23	36	14	
NC hardness ($CaCO_3$), mg/l (00902)	0	0	0	0	0	
S.A.R. (00931)	206	107	135	87	93	
Specific conductance (00095)	10800	7500	7120	5200	2850	
pH, standard units (00400)	7.7	8.9	9.6	9.2	8.6	
Temperature, water, °C (00010)	23.0	18.5	16.0	18.0	--	
Aluminum, Total, ug/l (01105)	--	--	--	--	--	
Arsenic, Total, ug/l (01002)	1	5	14	14	0	
Boron, dissolved, ug/l (01020)	1200	370	460	340	270	
Boron, Total, ug/l (01022)	--	380	--	--	--	
Lead, Total, ug/l (01051)	--	200(?)	--	--	--	
Lithium, Total, ug/l (01132)	--	220	--	--	70	
Mercury, Total, ug/l (71900)	0.0	0.0	--	--	0.0	
Selenium, Total, ug/l (01147)	--	0	0	1	0	
Sulfide, Total, mg/l (00745)	1.8	--	--	--	--	
Carbon, Total Organic, mg/l (00680)	500	29	--	34	4.8	

a/ Atresian flow with gas bubbles and dark oily substance accompanying the water Other values: oil and grease, 450 mg/l.

b/ Other values, total (dissolved plus suspended) in ug/l: Cd, 10; Cr,o; Cu, 180; Fe, 1200; Mn, 50; turbidity, 30 JTU; water level, 89.3 ft; well depth, 394ft.

c/ Water level, 36ft; well depth, 350 ft.

d/ Water level, 47ft; well depth, 274ft.

e/ Other values, total (dissolved plus suspended) in ug/l: Cd, <10; Cr, 230; Cu, 10. Oil separator pond at well.

Table F-4.--Chemical analyses of ground waters at or near the Bisti West reclamation study site - concluded

Analysis no.	Descriptive information
1	23N.13W.09.140 BLM Foshay Well near Bisti TP, NM (different formations);
2	Analyses from the September, 1973 report, "Reentry and Aquifer Testing, Apache 1
3	Foshay Well," by John W. Shomaker, consulting geologist. (Map site 76)
4	23N.14W.03.130 El Paso Natural Gas Company's Burnham water well No. 1. (4 mi W Bisti TP)
5	
6	

Item	Analysis number					
	1f	2g	3h	4i	5	6
Date of sample, YMD	730901	730830	730828	730924		
Time, 2400 clock	--	--	--	1430		
Geologic Unit	GLLP	WSRC	ENDR	WSRC		
Depth of sampling interval, ft	3660-3680	5052-5211	5816-5933	4980-5200		
Discharge, gpm	~4.2	200	100	--		
Silica (SiO_2), mg/l (00955)	--	17.9	18.4	43		
Iron (Fe), ug/l (01046)	11200?	240?	600?	10		
Calcium (Ca), mg/l (00915)	13	141	520	39		
Magnesium (Mg), mg/l (00925)	0	4	49	0.5		
Sodium (Na), mg/l (00930)	750	1175	3600	250		
Potassium (K), mg/l) (00935)	22	8	27	2.5		
Bicarbonate (HCO_3), mg/l (00440)	293	264	176	166		
Carbonate (CO_3), mg/l (00445)	168	0	0	0		
Sulfate (SO_4), mg/l (00945)	1586	2074	6089	490		
Chloride (Cl), mg/l (00940)	182	639	3622	17		
Fluoride (F), mg/l (00950)	3.5	2.0	3.0	1.0		
Nitrite+Nitrate (N), mg/l (00631)	0	0.10	0.14	0.03		
Orthophosphate (P), mg/l (00671)	1.4	0.10	0.10	0.14		
Dissolved solids, Sum, mg/l (70301)	3343	4458	15021	925		
Total hardness ($CaCO_3$), mg/l (00900)	33	370	1500	99		
NC hardness ($CaCO_3$), mg/l (00902)	0	154	1356	0		
S.A.R. (00931)	87.5	30.2	51.8	11		
Specific conductance (00095)	4081	6060	20000	1390		
pH, standard units (00400)	9.35	8.0	7.55	8.1		
Temperature, water, °C (00010)		60	58	61.0		
Aluminum, Total, ug/l (01105)	--	--	--	--		
Arsenic, Total, ug/l (01002)	--	--	--	--		
Boron, dissolved, ug/l (01020)	10000?	800?	2000?	--		
Boron, Total, ug/l (01022)	--	--	--	--		
Lead, Total, ug/l (01051)	--	--	--	--		
Lithium, Total, ug/l (01132)	--	--	--	--		
Mercury, Total, ug/l (71900)	--	--	--	--		
Selenium, Total, ug/l (01147)	--	--	--	--		
Sulfide, Total, mg/l (00745)	0	0	0	--		
Carbon, Total Organic, mg/l (00680)	--	--	--	--		

f/ Other values in mg/l(?): total Fe, 18.4; Ba, 0; Mn 0.16. Formation water mixed with drilling mud.

g/ Other values in mg/l(?): total Fe, 1.0; Ba, 0; Mn 0.16. Water clear and well sampled at end of pump test.

h/ Other values in mg/l (?): total Fe, 2.4; Ba, 0; Mn, 0.26. Water warm and clear but accompanied by strong hydrogen sulfide odor.

i/ Other values: water level, 702 ft; dissolved uranium, 07 ug/l; dissolved radium-226, 0.24pc/l.

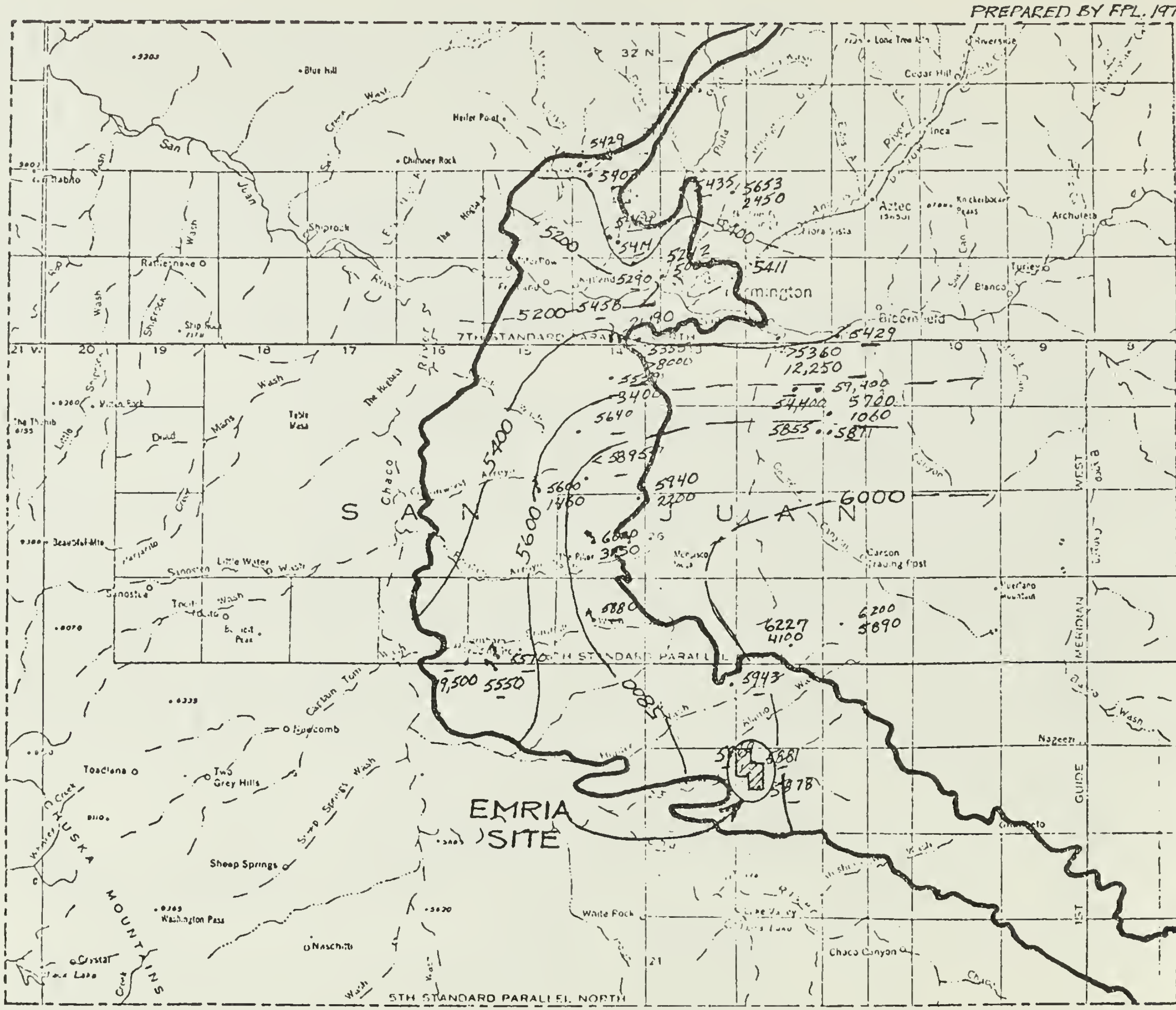

Figure F-1.--Potentiometric surface contours and specific conductances in the Kirtland-Fruitland Formation.

Explanation: . well; ɂ spring; upper number, water level in feet above MSL; lower number, specific conductance in micromhos per cm at 25°C; solid outline, formation outcrop area; potentiometric contour, 200 feet interval with datum at MSL (contour dashed where approximated)

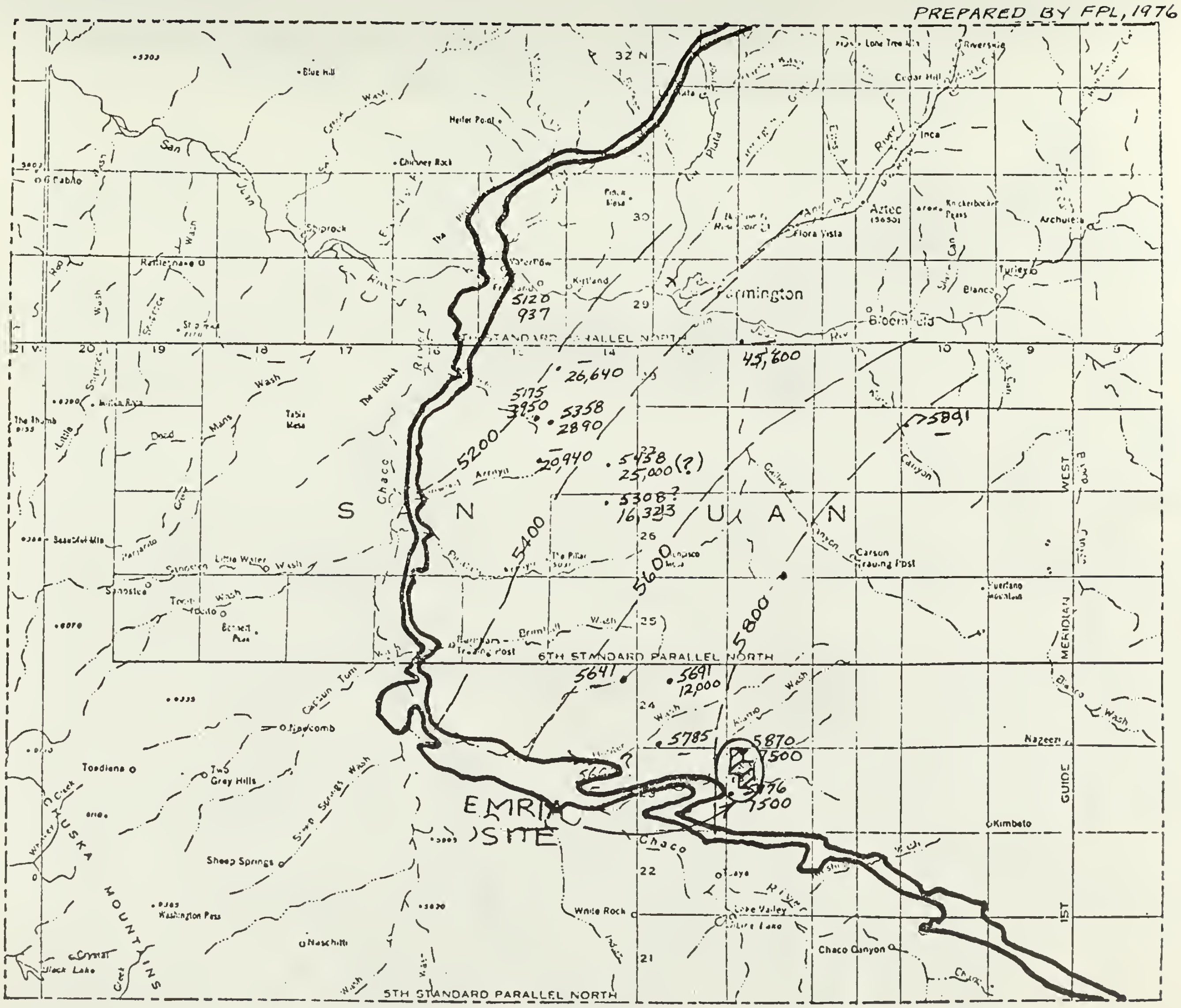

Figure F-2.--Potentiometric surface contours and specific conductances in the Pictured Cliffs Sandstone.
Explanation: (see figure F-1.)

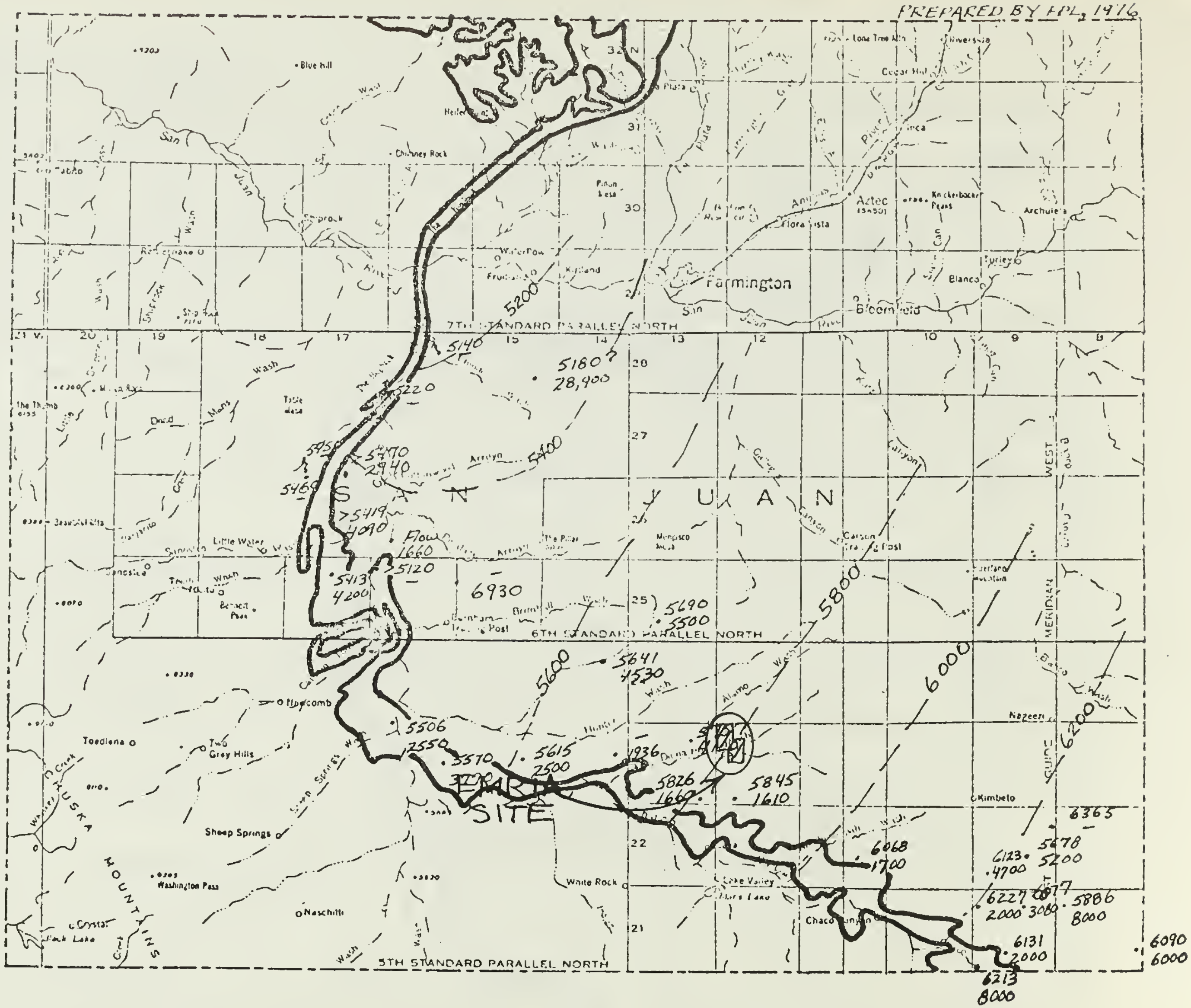

Figure F-3.--Potentiometric surface contours and specific conductances in the Cliff House Sandstone..

Explanation: (see figure F-1.)

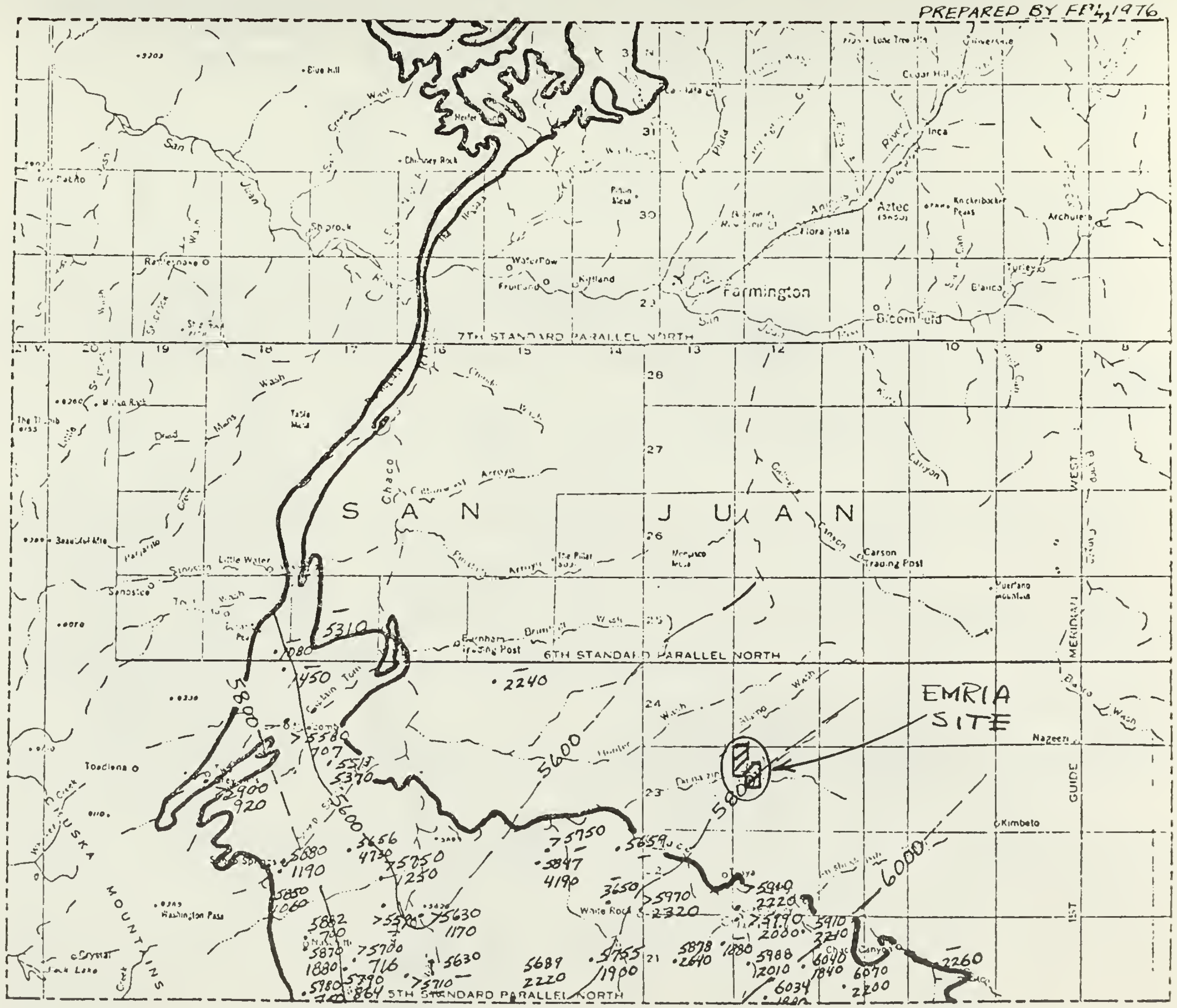

Figure F-4.--Potentiometric surface contours and specific conductances in the Menefee Formation

Explanation: (see figure F-1.)

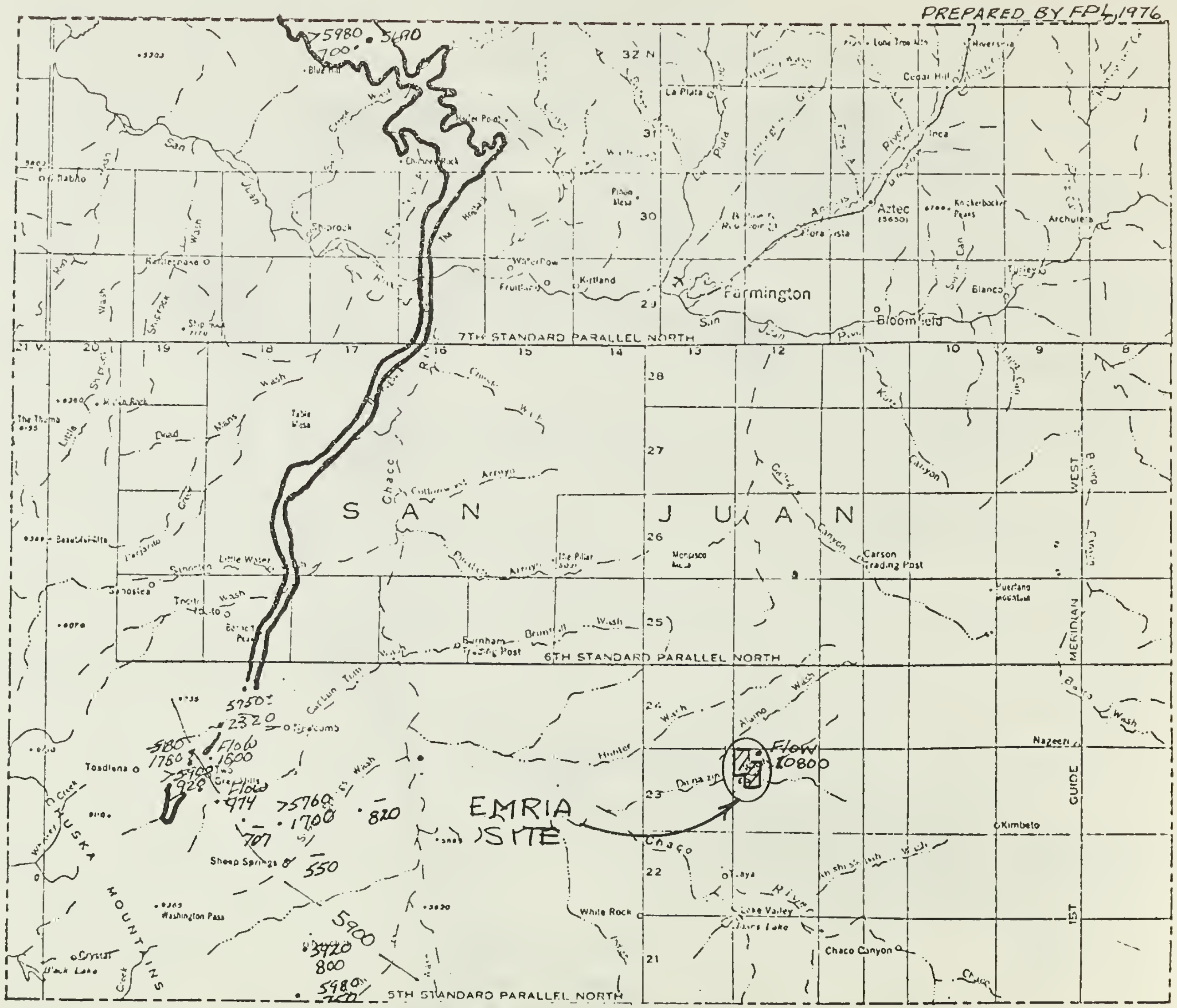

Figure F-5.--Potentiometric surface contours and specific conductances in the Point Lookout Sandstone.

Explanation: (see figure F-1.)

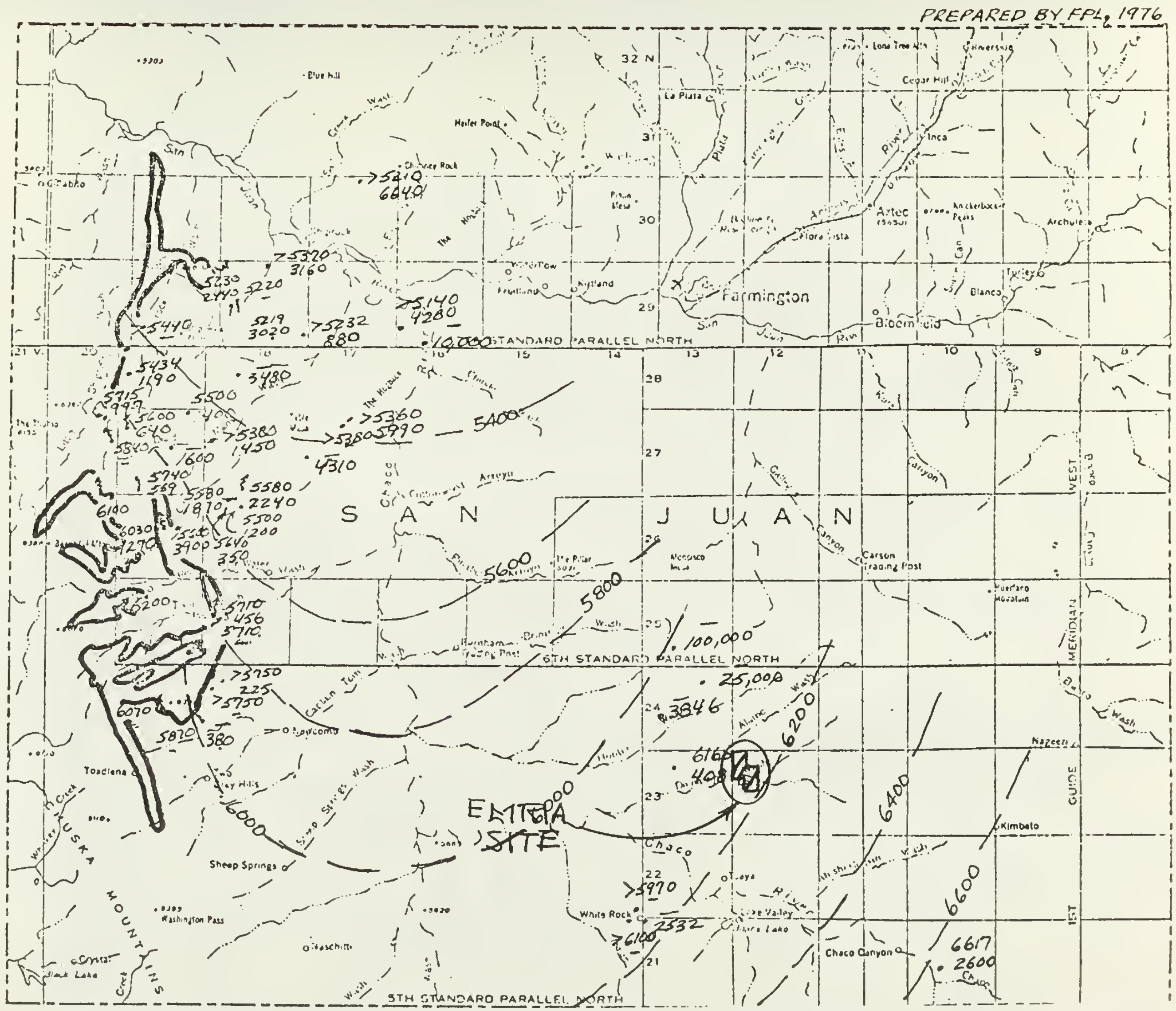

Figure F-6.--Potentiometric surface contours and specific conductances in the Gallup Sandstone.

Explanation: (see figure F-1.)

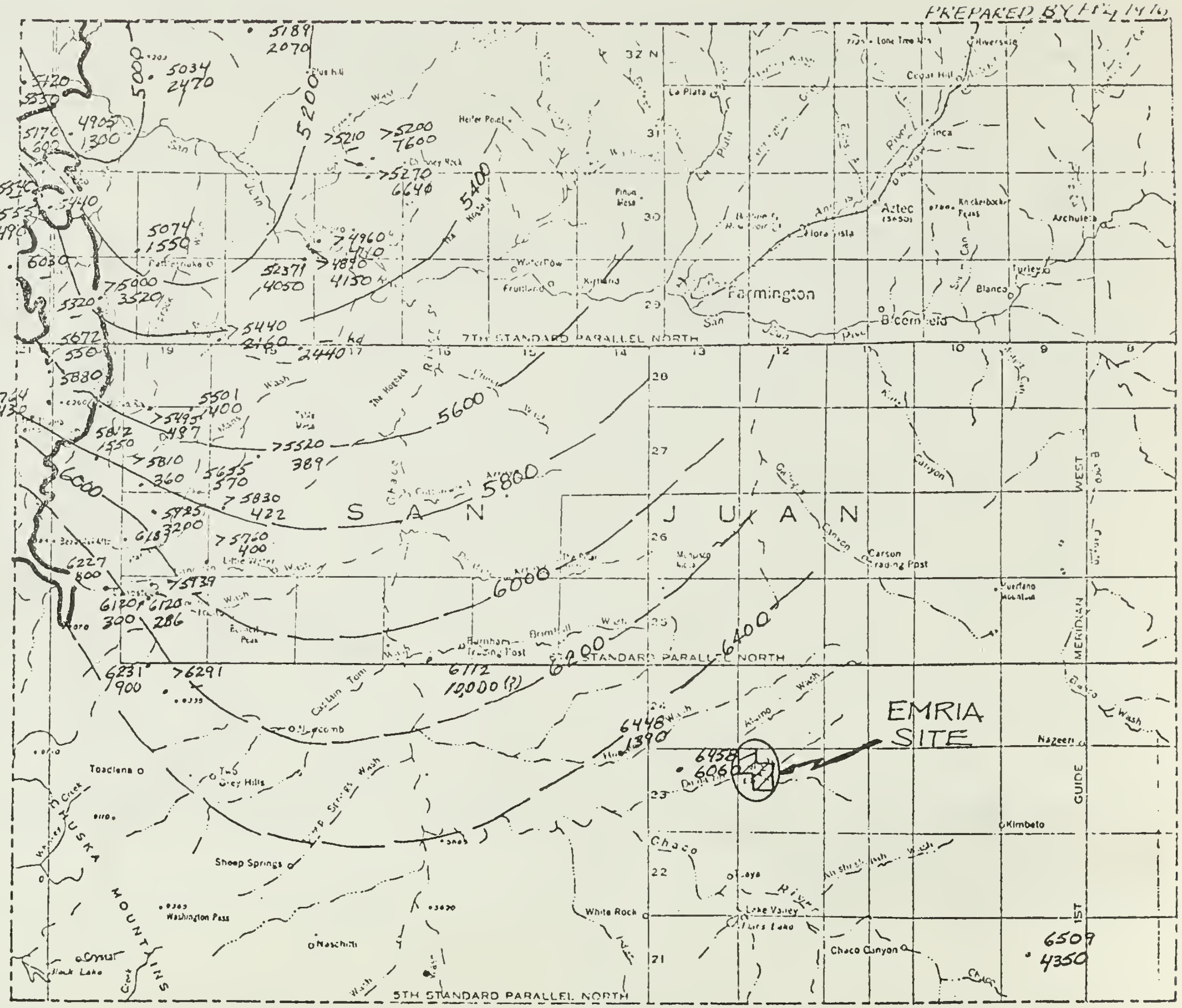

Figure F-7.--Potentiometric surface contours and specific conductances in the Morrison Formation (including Dakota Sandstone in some wells).

Explanation: (see figure F-1.)